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SVIC NOTES

KEEPING UP WITH TECHNOLOGY

Occasionally one hears the expression, "the half-life of an engineering education is a certain number of years." This means half of what we learn will be obsolete after a certain period of time. Due to the rapid advances in technology in many fields, some feel this period may be as short as 10-12 years; consequently an engineer's technical knowledge could be largely outmoded 10-15 years after graduation.

Even though an engineer's education continues after graduation from college, keeping technically up to date is even more important in the present climate of rapidly advancing technology. In addition to learning on the job, one could easily maintain their technical proficiency in the past by keeping up with the literature in their field or by attending meetings of professional societies; this was possible because technology advanced at a slower rate and less technical literature was published. However, this approach, by itself, is no longer viable for a number of reasons. Many different organizations have recognized this fact, and they are also aware of the shorter half-life of today's engineering education. As a result, many short courses have been held to help meet the continuing training needs of the engineers.

Many periodicals, including our own **Shock and Vibration Digest,** carry announcements of the short courses that are sponsored by the many different types of organizations. Some courses are designed to provide the specialized training that is needed, but that cannot be included in engineering curricula for lack of time or facilities. Other short courses are designed to upgrade engineers' knowledge of certain college level subjects by exposing them to the new theories or the new techniques that have been developed.

Whatever their purpose, engineering short courses are a valuable facility for helping engineers to keep technically up to date in their field. Not only do they refresh and extend an engineer's knowledge about a certain subject, they provide the resources and the starting point for further study.

R.H.V.

EDITORS RATTLE SPACE

REVIEW ARTICLES

The **Digest** is a secondary technical journal devoted to the organization, distillation, and review of the literature in the shock and vibration area. Review articles are one of the principal parts of the **Digest.** Articles dealing with specialized technology but written for the nonspecialist are prepared by members of the shock and vibration community. It is envisioned that these critical reviews of the literature and extensive bibliographies will help the specialist and those researchers beginning work in the area.

The literature review articles are a subjective alternative to the objective reports published in the "Abstracts from the Current Literature" section of the **Digest.** The 3,500-word review articles include introductory material pertinent to the area under discussion, references to technical information from articles and reports, and an evaluation of the new literature.

Recommendations on possible areas of new research are often mentioned. Coverage varies with the nature of the technical area: in some cases an article provides detailed coverage of a narrow area; in other areas an overview of a broad area is given.

One of the major concerns of the Technical Editor with regard to review articles has been the use of excessive mathematics. Although detailed mathematical coverage is sometimes essential to make a point, in general functional form will serve the purpose of conveying the message. The "lay" reader is put off by specialized mathematics and will not read such an article because it takes too much time to become familiar with the terminology. The same situation applies to the use of technical jargon.

At present we have an active group of literature reviewers; they are analyzing the literature of distinct subject areas on a three-year basis. The assigned subject areas encompass the entire shock and vibration field. If you have suggestions or comments on the literature reviews or wish to join the literature review program please contact me.

R.L.E.

SHOCK AND SEISMIC RESPONSE SPECTRA IN DESIGN PROBLEMS

Y. Matsuzaki* and S. Kibe**

Abstract. This is a review of recent literature on shock and seismic response spectra techniques. Applications of shock response spectra in design problems are discussed. Descriptions of determinations of seismic response spectra from recorded ground motions are also given.

Earlier review articles [1, 2] discussed technical literature related to the shock response spectrum (SRS) and maximal response – the peak response of a structure to the worst excitation. The present paper reviews the literature on these same problems from 1978 to 1981.

It has been very important to develop more accurate and efficient design methods for predicting structural loads and responses of complex systems in many engineering fields. For instance, the rapid development of space transportation systems, such as space shuttles and orbiters, has required techniques for analyzing many different kinds of payloads and loading conditions including emergency landings. As more regular and frequent service is scheduled for such systems, tighter restrictions will be imposed on total design time as well as cost. The shock response spectrum technique is well established and is easy to apply to the designs of structures subjected to shock excitations. The SRS has been used as a practical tool during both preliminary and final design stages of spacecraft and their payloads.

Voyagers I and II were designed with the aid of a modified SRS method [3]; the relative impedance of the spacecraft and launch vehicle was also taken into account [4] because load prediction by the conventional SRS procedure was too conservative. In order to examine the validity of the modified SRS and to obtain the acceleration spectra for a future design, measurements were made at the interface between the launch vehicles and Voyagers during launches and powered flights [3]. Because comparisons between measured and design values showed that most design loads were two to five times the maximum flight loads, it was concluded that the shock spectra/impedance technique provides conservative design loads and that the conservatism was reasonable.

At the design stage, the excitations that will be encountered are often not well defined and must be estimated according to theoretical or empirical assumptions. This is especially true in earthquake engineering because all available information is incomplete due to the fact that an earthquake is a natural phenomenon with many uncertain factors. Unlike shock excitations in many engineering problems, no earthquake has the same intensity and time response as any that took place and was recorded in the past. One important feature of the SRS approach is that the maximum response of the structure can be treated without knowledge of the details of the excitation. A large number of seismic designs of buildings and public facilities have been made with the aid of shock, or seismic response, spectra. Recent efforts in this area are intended to account for the effects of many seismic parameters.

In previous reviews [1, 2] the focus was on theoretical aspects of the shock response spectrum and maximal response approaches. The concepts of both approaches are straightforward, and it was concluded [2] that the theoretical developments had already matured. No significant theoretical progress has been made since the last review, as was predicted [2]. In this article, therefore, we shall discuss applications of shock response spectra in the design analyses of several structures and practical ways for determining seismic response spectra from recorded ground motions. It is assumed that readers are famil-

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iar with the fundamental characteristics of the SRS [1].

APPLICATIONS OF SRS IN DESIGN

Design analyses of structures subjected to base or ground excitations are presented in this section; a condition is that the SRS of the excitations is available. The SRS of the base excitation is the peak response spectrum of a single-degree-of-freedom (DOF) system to a given base excitation.

Long pipings, such as those in chemical or nuclear power plants, are supported at discrete points. Lee [5] used a velocity spectrum approach and proposed a simple design method for estimating a basic spacing L of the uniform piping between supporting points. He used a simply supported beam analysis and a modified acceleration spectrum $S_A(f)$ obtained from a specified acceleration spectrum $\hat{S}_A(f)$ according to the following equation (see Figure 1)

$$S_A(f) = \max_{f < f'} \hat{S}_A(f') \tag{1}$$

where f and f' are frequencies. The resulting spectrum $S_A(f)$ has a semi-monotonically decreasing envelope (SMDE); i.e.,

$$S_A(f_1) \geq S_A(f_2) \quad \text{for } f_1 < f_2$$

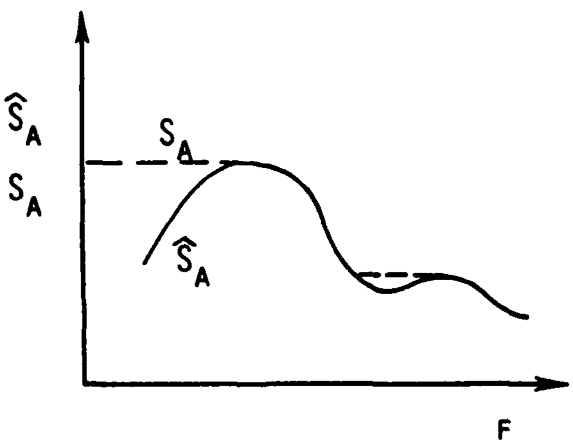

Figure 1. Specified Acceleration Spectrum $\hat{S}_A(f)$ and Semi-monotonically Decreasing Acceleration Spectrum $S_A(f)$

In other words, as the frequency of the structure becomes smaller, the acceleration applied has a tendency to increase. The SMDE spectrum guarantees that the simply supported beam model provides a conservative design for other beams of the same span. The reason is that the natural frequencies of the simply supported beam are lower than those of the corresponding modes of the other stiffer beams. The load on the beam due to ground motions is the inertia of the beam itself; therefore, the equation of motion is given as

$$\frac{d^2 M_n}{dx^2} = m\, A_n(x) \tag{2}$$

A_n, M_n, and m are, respectively, maximum acceleration, bending moment of the nth mode, and mass per unit length.

$$A_n(x) = \Gamma_n S_{An} \phi_n(x) \tag{3}$$

$$\phi_n(x) = \sin(n\pi x/L) \tag{4}$$

$$\Gamma_n = \frac{\int_0^L m\phi_n(x)dx}{\int_0^L m\phi_n^2(x)dx} = \begin{cases} \dfrac{4}{n\pi} & (n = \text{odd}) \\ 0 & (n = \text{even}) \end{cases} \tag{5}$$

The notations ϕ_n and Γ_n denote the nth normal mode and its participation factor, respectively. The induced bending stress is

$$\sigma_n(x) = \frac{M_n(x)}{z} \tag{6}$$

where z is the sectional modulus of the beam. Because

$$\max_x [\phi_n(x)] = 1$$

the maximum modal bending stress becomes

$$(\sigma_n)_{max} = \left(\frac{L}{n\pi}\right)^2 \frac{m}{z} \Gamma_n S_{An} \tag{7}$$

$$= \frac{8}{n\pi^2} \frac{m}{z} C_f S_{Vn} \tag{8}$$

where

$$C_f = \frac{\pi}{2}\sqrt{\frac{EI}{m}} \tag{9}$$

$$S_{Vn} = S_{An}/2\pi f_n \tag{10}$$

$$f_n = \left(\frac{n}{L}\right)^2 C_f \tag{11}$$

S_{Vn}, f_n, E, and I denote the pseudo-velocity spectrum, natural frequency, Young's modulus, and moment of inertia, respectively. Consider the square-root-sum-square (SRSS) of the modal stress to evaluate the maximum induced stress.

$$\sigma = \left[\sum_n (\sigma_n)^2{}_{max}\right]^{1/2} \tag{12}$$

Let S_{V0} be the maximum of S_{Vn}'s for all modes; i.e., S_{V0} = max S_{Vn}. Substitution of equation (8) into equation (12) and mathematical manipulation yield a simple relationship between the SRSS and S_{V0}.

$$\sigma = C_\sigma S_{V0} \tag{13}$$

where

$$C_\sigma = D_p \left(\frac{Em}{2I}\right)^{1/2} \tag{14}$$

D_p is the pipe diameter.

A design procedure follows.

- Calculate C_σ, C_f, and $V = \sigma_a/C_\sigma$ for an allowable σ_a.
- Read the frequency f at which V intersects the S_V curve redrawn by equation (10) from the S_A curve given.
- Determine the basic span from $L = \sqrt{C_f/f}$.

Compared with the method based on the acceleration spectrum, the method above is more straightforward. In the acceleration spectrum method previously proposed, equation (7) is used to calculate the maximum stress in place of equation (8) or equation (12); the latter includes effects of the higher modes. Equation (7) shows that the maximum stress depends on S_A as well as L when the cross sectional parameters of the beam are fixed. Because S_A is a function of the natural frequency f, and consequently the span L, it is necessary to iterate calculations to choose L so that the maximum bending stress is σ_a.

When the center of stiffness of a structure does not coincide with that of the mass, translational excitations at the base cause not only translational motions but also rotational motions of the structure. This is the case for asymmetric buildings during earthquakes. Tso and Dempsey [6] studied the response of a two-degree-of-freedom model with such an eccentricity. They proposed a method for predicting the maximum value of the rotational moment and dynamic eccentricity from the SRS of the base excitation. Dynamic eccentricity is a parameter used in the seismic design code of asymmetric buildings.

The rotational response θ about the center of stiffness due to the base acceleration $\ddot{u}_b(t)$ can be expressed [6] as

$$\theta(t) = K_n [D_1(t) - D_2(t)] \tag{15}$$

K_n is a quantity determined by the two normal modes of an undamped system shown in Figure 2. $D_i(t)$ is the normal coordinate representing the time history of the normal mode i of natural frequency ω_i, which is subjected to $\ddot{u}_b(t)$; the damping of η_i is taken into account. The maximum value of $D_i(t)$ is given using the acceleration spectrum $S_A(\omega)$.

$$(D_i)_{max} = \frac{S_A(\omega_i)}{\omega_i^2} \tag{16}$$

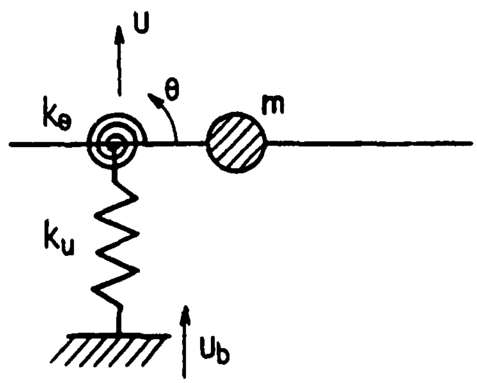

Figure 2. Nonsymmetric Model with a Single Mass

Because the rotational moment is proportional to θ, the maximum rotational moment $(M_i)_{max}$ due to the mode i can be written as

$$(M_i)_{max} = K \frac{S_A(\omega_i)}{\omega_i^2} \tag{17}$$

K is obtained by multiplying K_n by the stiffness coefficient k_θ. The maximum value of the rotational moment M_{max} due to the total response has been evaluated by a revised version of the square-root-sum-square (SRSS) defined [7] as

$$M_{max} = \left\{ (M_1)^2_{max} + (M_2)^2_{max} - 2(M_1)_{max}(M_2)_{max}/(1+\epsilon^2) \right\}^{1/2} \tag{18}$$

where

$$\epsilon = \frac{\sqrt{1-\eta^2}}{\eta} \cdot \frac{\omega_2 - \omega_1}{\omega_2 + \omega_1} \tag{19}$$

with $\eta = \eta_1 = \eta_2$

The modal dynamic eccentricity $(e_d)_i$ is defined as the distance from the center of stiffness to a point of a structure at which a force $mS_A(\omega_y)$ is applied such that the modal rotational moment induced is equal to $(M_i)_{max}$

$$(e_d)_i = \frac{(M_i)_{max}}{mS_A(\omega_y)} = \frac{KS_A(\omega_i)}{m\omega_i^2 S_A(\omega_y)} \tag{20}$$

where ω_y is the translational frequency when the rotation is prevented, and m is the mass of the structure. The total dynamic eccentricity can also be estimated by the revised SRSS.

Light equipment is often attached to a large structure that is subjected to base excitations. When the natural frequency of the equipment is close or equal to one of the natural frequencies of the main structure, the equipment responds in an unexpected manner because a dynamic interaction occurs between structure and equipment. For example, Figure 3 [8] shows that the amplification factor of the response of the equipment with damping has two dominant peaks closely spaced in a frequency range close to the frequency of the equipment.

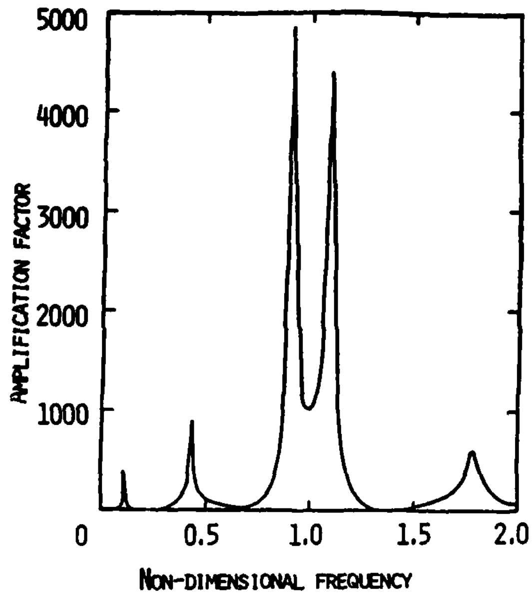

Figure 3. Amplification Factor vs Frequency Normalized with Respect to the Natural Frequency of the Equipment

Kelly and Sackman [8] assumed that the SRS of the base motion was available and obtained an analytical relationship between the response of the equipment and the base motion. The structure-equipment system was represented by an undamped shear beam connected to a mass by a spring. The natural frequency of the equipment ω_0 was assumed to be close to that of the nth mode of the main structure. A Laplace transform method was used to evaluate the impulse response function h(t) of the tuned equipment. The inverse transform of the function in the Laplace domain was approximated by calculating only the residues associated with the above-mentioned two dominant peaks, so that h(t) was analytically expressible as

$$h(t) = (-1)^{\frac{n-1}{2}} \frac{C}{\omega_0} \left(\sin \xi t \cos \omega_0 t - \frac{5}{2}\sqrt{\frac{\gamma}{2}} \cos \xi t \sin \omega_0 t\right) \tag{21}$$

where γ is a ratio of the mass of the equipment to that of the entire structure and

$$C = \left(\frac{n\pi}{2} \sqrt{\frac{\gamma}{2}}\right)^{-1} \tag{22}$$

$$\xi = \omega_0 \sqrt{\frac{\gamma}{2}} \tag{23}$$

The convolution theorem was used to formulate the response of the equipment to an arbitrary base acceleration $\ddot{u}_b(t)$ as

$$Y(t) = \int_0^t \ddot{U}_b(\tau)h(t-\tau)d\tau \tag{24}$$

When the shock duration is short and the mass ratio is small -- that is, $\xi t \ll 1$ and $\xi \ll \omega_0$ -- the maximum value of the response can be evaluated analytically [1]:

$$Y_{max} = \frac{C}{\omega_0} \max \left[\int_0^t \ddot{U}_b(\tau)\cos\left\{\omega_0(t-\tau)\right\} d\tau\right]$$

$$= \frac{CS_V(\omega_0)}{\omega_0} \tag{25}$$

$$= CS_D(\omega_0) \tag{26}$$

Max [. . . . .] of the right-hand side of equation (25) is equal to the velocity spectrum S_V for a single DOF system with frequency ω_0. S_D denotes a pseudo-displacement spectrum of the base motion. Similarly,

$$\ddot{Y}_{max} = CS_A \tag{27}$$

S_A is an acceleration spectrum of the base motion. This analysis was extended to an undamped discrete system of n DOF; a single DOF mass-spring represented equipment [9].

The response of an n DOF system subjected to base excitation is often treated by introducing an equivalent model with the base fixed to simplify the analysis. Nelson [10] studied the effect of damping on the SRS of a mass-spring system with multi-DOF using such a model.

Experimental simulation and computational generation of the SRS are important. It is necessary to produce shock forces specified by a given SRS in order to perform shock tests on a real package or a simulated model in a laboratory. The shock force produced must satisfy the peak amplitude, domain frequency, and duration of the loadings. Bai and Thatcher [11] used a metal-to-metal impact technique and a time/data analyzer to obtain a high g level shock spectrum, such as the MIL-STD-1540A, which requires a maximum acceleration of 18,000 g at 2,000 Hz.

The test setup consisted of a pendulum hammer and a beam resonant fixture on which an accelerometer was mounted to measure the shock transient generated. Beams of different lengths were used according to the major frequency of the spectrum. A small aluminum mass was attached to the impact area to change the loading duration. Although the controllability and repeatability of the tests were not fully satisfactory, the spectrum obtained from the generated shock force was shown to lie within a tolerable band except at the lower frequency range.

One popular technique for generating an SRS is to use a digital recursive filter that simulates a single DOF system. The output of the filter to a sampled input represents the response of the system. The peak response is repeatedly searched by changing the natural frequency. If the natural frequency takes a value corresponding to some fraction of the sampling period T or the frequency is equal to 1/2T, an impulsive simulation gives erroneous results.

In the *impulsive method*, a continuous input function is approximated by a series of impulses generated at each sampling time. It has been claimed [12] that errors occur because of mutual cancellation of impulsive responses. For instance, a square pulse with the same duration as the sampling period T is represented by two impulses with the same amplitude that are generated at the first two sampling times; i.e., t = 0 and T. If the system has a natural frequency of 1/2T and small damping, its total response due to the impulses becomes quite small except for the period between the first and second sampling times ($0 \leq t \leq T$). The reason is that two impulsive response h(t) and h(t−T) cancel each other after the second sampling time $t > T$. Such an impulsive approximation for the square pulse gives unreasonably low estimations for peak residual response. This sort of cancellation can also occur for more complex input functions so long as the natural frequency is close to 1/2T. Smallwood [12] accounted for this cancellation and improved the filter design. An input was *simulated* by a continuous function that was piecewise linear in each period between every sampling

time. The recursive formula for calculating the total response was obtained with the aid of a z-transform. Good results were obtained over a wide range of frequency from much less than the sampling rate to many times the sampling rate.

SEISMIC RESPONSE SPECTRUM

In seismic design it is important to properly define earthquake ground motions from available seismic records. This is not a simple task, however. The ground motions caused by the same earthquake differ from one recording station to another because the transmission of motion and energy depends on many parameters. They include earthquake magnitude, hypocentral distance, soil condition, and direction of ground motion. In addition, some of these parameters cannot be evaluated accurately.

Several methods have been proposed to construct seismic response spectra from accelerograms using empirical or theoretical assumptions. Regression analysis represents a typical approach. A regression model of the spectrum $S(\omega)$ is expressed in terms of the above-mentioned seismic parameters and their associated coefficients. An example is given below [13]:

$$\log_{10} S(\omega) = \log_{10} a(\omega) + b(\omega)M - C(\omega)\log_{10}(R + 25) + \log_{10} r \tag{28}$$

where a, b, c are the coefficients to be determined; M, R, and r are, respectively, the magnitude, hypocentral distance (km), and a residual used to adjust deviations of individual accelerograms. This expression (equation 28) has been used to represent acceleration, velocity, or displacement spectra. The peak responses of the building are usually calculated from a large number of recorded ground motions and are applied to equation (28) together with the values of the seismic parameters in order to determine the coefficients a, b, and c.

More complex functions have been used by Trifnac and Anderson [14] to add the effects of soil conditions, and direction of the ground excitation. They also considered a confidence level of the response that would not exceed a specified value.

Another approach is to construct the seismic response spectrum from a probabilistic point of view. When many spectra are examined for excitations with different intensities, it is common to use a normalized spectrum d that is obtained by dividing the spectrum s by the peak response y_p of the corresponding response; that is, $d = s/y_p$. The normalized spectrum represents a response spectral shape, which is called a dynamic amplification factor.

Dynamic amplification factors and peak responses have been treated as random variables [15] to evaluate a probability distribution function of the response spectra. Let S, D, and Y be the random variables corresponding to s, d, and y_p, respectively. Assume that D and Y are statistically independent. The probability distribution function on the response spectra $F_S(s)$ can be written as

$$\begin{aligned} F_S(s) &= P(S < s) = P(YD < s) \\ &= \int_0^\infty \int_0^{s/d} p_{YD}(y,d)\,dy\,dd \\ &= \int_0^\infty p_D(d) F_Y(s/d)\,dd \end{aligned} \tag{29}$$

P and p_{YD} are, respectively, a probability and a joint probability density function of Y and D, and

$$p_{YD}(y,d) = p_Y(y)p_D(d) \tag{30}$$

because of the independence of Y and D. A method for calculating the seismic response spectra from the distribution function $F_S(s)$ was consistent with an assigned probabilistic risk [15]. The probability density function p_Y of the peak response was determined from a seismic model based on the assumption of Poisson earthquake occurrences [16]; the dynamic amplification factor was assumed to have a gamma distribution.

Finally, let us discuss a procedure to obtain a seismic response spectrum with which such public facilities as hospitals and dams should be designed. In order to guarantee with a high level of confidence the survival of a building during a major earthquake, a worst-case design against the severest conditions is inevitable because sufficient seismic information is unavailable.

A design philosophy based on the concept of a critical excitation has been proposed [17]. The

critical excitation is defined as the excitation, among a class of excitations, that produces the largest response peak of the structure under consideration. As has been shown [2], a theoretical solution for the critical excitation of the acceleration $\ddot{x}_c(t)$ is [17]

$$\ddot{x}_c(t) = I_m h(-t) \Big/ \left\{ \int_0^T h^2(t)dt^2 \right\}^{1/2} \tag{31}$$

I_m is the maximum intensity of the excitations defined by

$$I_m^2 \geq \int_0^T \ddot{x}^2(t)dt \tag{32}$$

and h(t) is again the impulse response function of the structure. This solution proved to be too conservative for design purposes, however. The concept of a subcritical excitation chosen from a class of excitations expressed in terms of a linear combination of recorded accelerations $\ddot{x}_i(t)$ was introduced [18]:

$$\ddot{x}(t) = \sum_{i=1}^{n} a_i \ddot{x}_i(t) \tag{33}$$

The coefficients a_i of the subcritical excitation were determined by minimizing

$$\int_0^T [\ddot{x}_c(t) - \ddot{x}(t)]^2 dt$$

under the constraint of equation (32).

Recently, Wang and Yun [19] presented a critical response spectrum determined on the basis of a critical excitation among the class of excitations defined by equation (33). The response y(t) of the structure to the acceleration by equation (33) is written as

$$\begin{aligned} y(t) &= \sum_{i=1}^{n} \int_0^T a_i \ddot{x}_i(\tau) h(t-\tau) d\tau \\ &= \sum_{i=1}^{n} a_i y_i(t) \end{aligned} \tag{34}$$

where $y_i(t)$ is the response to $\ddot{x}_i(t)$. Because the intensity of the excitations does not exceed a given value I_m,

$$I_m \geq \sum_{i=1}^{n} \sum_{j=1}^{n} a_i a_j \ddot{X}_{ij} \tag{35}$$

where

$$\ddot{X}_{ij} = \ddot{X}_{ji} = \int_0^T \ddot{x}_i \ddot{x}_j \, dt \tag{36}$$

Equations (34) and (35) are used to determine the critical excitation; i.e., a set of coefficients a_i from

$$0 = \frac{\partial}{\partial a_j} \left(\sum_{i=1}^{n} a_i y_i + \lambda \sum_{j=1}^{n} \sum_{i=1}^{n} a_i a_j \ddot{X}_{ij} \right) \tag{37}$$

$$j = 1, 2, \ldots, n$$

where λ is a Lagrange multiplier. Let **A** and **Y** denote n-dimensional column vectors with the components a_i and $y_i(t)$, and $\ddot{\mathbf{X}}$ an nxn-dimensional matrix with the components $\ddot{X}_{ij}$. Obtain from equation (37)

$$\ddot{\mathbf{X}}\mathbf{A} = -\frac{1}{2\lambda} \mathbf{Y}(t)$$

whence

$$\mathbf{A} = -\frac{1}{2\lambda} \ddot{\mathbf{X}}^{-1} \mathbf{Y} \tag{39}$$

whenever **X** is invertible. Because of

$$\mathbf{A}^T \ddot{\mathbf{X}} \mathbf{A} \leq I_m^2 \tag{40}$$

Y(t) is maximized for fixed t when

$$\lambda = \frac{1}{2I_m} \left[\mathbf{Y}^T \ddot{\mathbf{X}}^{-1} \mathbf{Y} \right]^{1/2} \tag{41}$$

Substitution of equation (41) into equation (39) yields the set of maximizing coefficients a_i. The peak responses to the critical excitations determined were numerically calculated for a number of natural frequencies in order to construct a critical response spectrum.

CONCLUDING REMARKS

It is again concluded that, from a theoretical viewpoint, the shock response spectrum approach has matured and that no significant progress has been made. In practical applications, however, ad hoc treatments are being used to modify the original concept of the SRS and to broaden the range of validity of the shock response spectrum approach.

REFERENCES

1. Matsuzaki, Y., "A Review of Shock Response Spectrum," Shock Vib. Dig., 9 (3), pp 3-12 (1977).

2. Matsuzaki, Y., "Shock Response Spectrum and Maximal Response," Shock Vib. Dig., 12 (3), pp 11-15 (1980).

3. Chen, J.C., Garba, J.A., and Day III, F.D., "Voyager Design and Flight Loads Comparison," J. Spacecraft, 16 (1), pp 27-34 (1979).

4. Bamford, R. and Trubert, M.R., "A Shock Spectra and Impedance Method to Determine a Bound for Spacecraft Loads," AIAA Paper 75-011, Denver, CO (May 27-29, 1975).

5. Lee, M.Z., "Seismic Restraint Spacing: A Velocity Spectrum Method and Other Considerations," ASME Paper 79-PVP-17 (1979).

6. Tso, W.K. and Dempsey, K.M., "Seismic Torsional Provisions for Dynamic Eccentricity," Intl. J. Earthquake Engrg. Struc. Dynam., 8, pp 275-289 (1980).

7. Newmark, N.M. and Rosenblueth, E., Fundamentals of Earthquake Engineering, Prentice-Hall, Englewood Cliffs, NJ (1971).

8. Kelly, J.M. and Sackman, J.L., "Response Design Methods for Tuned Equipment-Structure Systems," J. Sound Vib., 59 (2), pp 171-179 (1978).

9. Kelly, J.M. and Sackman, J.L., "Shock Spectra Design Methods for Equipment-Structure Systems," Shock Vib. Bull., U.S. Naval Res. Lab., Proc. No. 49, Pt. 2, pp 171-176 (1979).

10. Nelson, F.C., "The Response Spectrum Method of Solution for Displacement Excitation," Shock Vib. Bull., U.S. Naval Res. Lab., Proc. No. 51, Pt. 2, pp 205-209 (1981).

11. Bai, M. and Thatcher, W., "High G Pyrotechnic Shock Simulation Using Metal-to-Metal Impact," Shock Vib. Bull., U.S. Naval Res. Lab., Proc. No. 49, Pt. 1, pp 97-100 (1979).

12. Smallwood, D.O., "An Improved Recursive Formula for Calculating Shock Response Spectra," Shock Vib. Bull., U.S. Naval Res. Lab., Proc. No. 51, Pt. 2, pp 211-216 (1981).

13. Faccioli, E., "Response Spectra for Soft Soil Sites," ASCE Proc., Specialty Conf. Earthquake Engrg. Soil Dynam., Pasadena, CA, pp 441-456 (June 19-21, 1978).

14. Trifnac, N.D. and Anderson, J.G., "Estimation of Relative Velocity Spectra," Symp. Earthquake Engrg., Univ. of Roorkee, Roorkee, India, pp 9-14 (Oct 5-7, 1978).

15. Kiremidjian, A.S. and Shah, H.S., "Probabilistic Site-Dependent Response Spectra," ASCE J. Struc. Div., 106, pp 69-86 (1980).

16. Der Kiureghian, A. and Ang, A.S-H., "A Fault-Rupture Model for Seismic Risk Analysis," Bull. Seismol. Soc. Amer., 67, pp 1173-1194 (1977).

17. Drenick, R.F., "Model-Free Design of Aseismic Structures," ASCE J. Engrg. Mech. Div., 96, pp 483-493 (1970).

18. Wang, P.C., Drenick, R.F., and Wang, W.Y.L., "Seismic Assessment of High-Rise Buildings," ASCE J. Engrg. Mech. Div., 104, pp 441-445 (1978).

19. Wang, P.C. and Yun, C.D., "Site-Dependent Critical Design Spectra," Intl. J. Earthquake Engrg. Struc. Dynam., 7, pp 569-578 (1979).

LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains an article about impact loading in filamentary structural composites.

Drs. R.L. Sierakowski and S.K. Chaturvedi of the Department of Engineering Sciences, University of Florida, have written a paper summarizing work on the impact loading response of filamentary type composite materials. Types of composites included are: boron-fiber, chopped-fiber, glass-fiber, graphite or carbon-fiber, hybrids, kevlar-fiber with polymer matrix, and metal-matrix.

IMPACT LOADING IN FILAMENTARY STRUCTURAL COMPOSITES

R.L. Sierakowski* and S.K. Chaturvedi*

***Abstract.** This article summarizes work on the impact loading response of filamentary type composite materials. The following types of composites are included: boron-fiber, chopped-fiber, glass-fiber, graphite or carbon-fiber, hybrids, Kevlar-fiber with polymer matrix, and metal-matrix.*

INTRODUCTION

This review summarizes work on the impact dynamics and impact loading response of filamentary type composite materials at sub-penetration velocities. In general, research into the dynamic response of advanced structural composites can be divided into several areas:

- propagation of nondestructive pulses in such materials
- damage tolerance of the material including transverse cracking, delamination, and fiber breakage
- global and/or local failure of structural composites as a result of the impact loading

Global and/or local failure can include but is not limited to penetration or perforation of the structural member. In addition, the residual load-bearing capacity or some demonstrated and useful performance index for the system can be exceeded; thus a requirement for categorizing the structural system as failed is needed.

In the 1970s several technical meetings and publications [1-4] were exclusively devoted to dynamic impact problems that were known as foreign object damage ((FOD) problems. Various aspects of materials response – for example, modeling of impact phenomena, wave propagation, damage tolerance, measurements and correlations of residual properties, and failure modes and mechanisms -- were discussed. Research activities in recent years have resulted in the publication of some interesting review articles summarizing the state of the art. Lee and Ting [5] in an excellent review article concentrated on problems related to pulse propagation and discussed both theoretical and experimental investigations on various composite systems. Review articles by Sun and Sierakowski [6] and Takeda and Sierakowski [7] emphasized problems of damage initiation and propagation and failure and fracture mechanisms.

The purpose of the present article is to supplement the previous ones [6, 7]; it includes new information available and an appendix containing quantitative data in tabular form. Attention is focused on the transverse response of continuous, chopped, and hybrid filamentary structural composites of both the nonmetal and metal matrix type over a range of impact velocities up to and including the ordnance regime (1300 m/sec). Consideration is also given to both hard and soft body impactors acting upon the composite target materials with local and global response noted. Principal interest is on experimental data as a basis for generating information and damage models. For interrogating impact damage, the mechanisms of damage and modes of failure, when available, have been noted. Such information as damage toughness, impact toughness, and some measure of a residual property characterizing the material is noted when it is available. Finally the important parameters associated with the projectile (e.g., material, velocity, nose shape, mass, angle of strike obliquity) and target (e.g., material, geometric and stacking sequence, impact energy, flexural and shear wave speeds) are noted.

To cite the reference literature used as a data base and as an attempt to systematize the information collected, a tabular format has been introduced. It is hoped that this presentation will provide a means for rapid search scans for composite impact data needed

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by an active researcher in the field. Furthermore, it is hoped that the tables will allow readers to identify some of the important impactor-target interaction parameters that characterize failure processes in various composite systems.

It is recognized that some important contributions may have been overlooked or gone unnoticed by the authors. The authors will be most grateful if appropriate references were brought to their attention so that they can be incorporated in future publications.

FUTURE RESEARCH

The projectiles used can be broadly categorized as hard-body and soft-body impactors that introduce widely different material response on both local and global levels. The fracture and failure modes exhibited by polymer-matrix composites are not necessarily carried over as such for metal-matrix composite systems under the same impact situations.

Although much work has been reported on the effects of fibers, resins, stacking sequence, and hybridization of materials response, the fundamental parameters for designing against impact loading have not been adequately demonstrated. One reason is the fact that different investigators use widely different impactor-target systems, and a systematic and thorough study has not been done. However, some interesting observations should be noted; for example, in graphite, glass and Kevlar composite systems a delamination type failure mode appears to be dominant in the subperforation range. In addition, both glass and Kevlar systems appear to have better impact resistance than graphite although the latter is stronger and stiffer. Any approach to systematize this behavior should include the fact that graphite fibers have relatively low fracture strains and are thus prone to localized failure without efficiently dissipating impact energy to a larger domain.

The damping characteristics of individual systems should also be significant in the impact response. Hybrid systems of glass, graphite, and Kevlar fibers should be more efficient when the stiffer and stronger graphite lamina can be sandwiched between glass and graphite. The result is a composite system with stiffness and strength as well as impact tolerance. In cases in which delamination types of failure are to be avoided, introduction of three-dimensional weaves should be advantageous.

Assessments of damage and characterization of residual mechanical properties require careful screening of the many NDT interrogation techniques currently available. It is generally recognized that no single scanning technique is ideal for composites because of the scope of interactive failure modes. A combination of such techniques should be delineated in a flexible format for the various composite systems in use. Ultrasonic and radiographic techniques appear to be most promising at present.

Efforts are needed in the area of damage modeling and assessment of residual composite properties. Preliminary attempts based upon the concepts of linear elastic fracture mechanics have been made for continuous fiber composites [8] as well as for chopped fiber composites. In view of the complex interactive failure modes for continuous composites, modeling based upon the concepts associated with self-similar crack-growth might not be meaningful.

As can be seen from the tabular data in the appendix, many impact studies were done using Charpy and Izod impact tests. It is possible that such tests are not adequate indicators of the FOD resistance of composite materials because of the low loading rates. The currently available data base is not large enough to assess the role of strain-rate sensitivity for the various composite systems in use.

In the area of modeling of impact loading the work reported so far is inadequate to provide a conclusive commentary insofaras the response of different composite systems is concerned. A hydrodynamic model of bird (soft-body) impact has recently been reported by Wilbeck and Barber [9]. On the other hand some recent attempts for hard-body impact modeling in the relatively low velocity regime are worth mentioning [10, 11]. However, none of these models takes into account damage initiation and propagation; such data are essential for predicting high-velocity impact response. An attempt to develop a model synthetic bird for use in engine blade impact testing has also been made [12].

It should be emphasized that the following additional research areas are in need of a data base if a comprehensive picture of structural composite

materials response in the entire domain of impact loading is to be obtained:

- impact loading and damage growth of prestressed specimens
- impact response modeling and characterization of specimens possessing various kinds of damage. This could require the use of specimens containing artificial simulated damage modes; e.g. *artificial delamination using teflon inserts* during specimen fabrication.
- change in impact response and fracture and failure modes of composites subjected to environmental degradation

REFERENCES

1. AFML-FOD Mtg., Bergamo Center, Dayton, OH (Apr 20-21, 1972).

2. Composites Recast, Executive Summary Report, AFML, Wright-Patterson Air Force Base, Dayton, OH (Aug 1972).

3. AFML-FOD Mtg., Bergamo Center, Dayton, OH (May 30-31, 1973).

4. Foreign Object Impact Damage to Composites, ASTM STP 568 (1975).

5. Lee, T.C. and Ting, T.C.T., "A Review of Dynamic Response of Composites," AMMRC TR 78-20 (Apr 1978).

6. Sun, C.T. and Sierakowski, R.L., "Recent Advances in Developing FOD Resistant Composite Materials," Shock Vib. Dig., 7 (2), pp 1-8 (1975).

7. Takeda, N. and Sierakowski, R.L., "Localized Impact Problems of Composite Laminates," Shock Vib. Dig., 12 (8), pp 3-10 (1980).

8. Husman, G.E., Whitney, J.M., and Halpin, J.C., "Residual Strength Characterization of Laminated Composite Subjected to Impact Loading," Foreign Object Impact Damage to Composites. ASTM, STP 568, pp 92-109 (1975).

9. Wilbeck, J.S. and Barber, J.P., "Bird Impact Loading," Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 48, Pt. 2, pp 115-122 (1978).

10. Dobyns, A.L. and Porter, T.R., "A Study of the Structural Integrity of Graphite Composite Structure Subjected to Low Velocity Impact," Poly. Engrg. Sci., 21 (8), pp 493-498 (1981).

11. Tan, T.M. and Sun, C.T., "Wave Propagation in Graphite/Epoxy Laminates due to Impact," NASA CR-168057 (Dec 1982).

12. Wilbeck, James S. and Rand, James L., "The Development of a Substitute Bird Model," J. Engrg. Power, Trans. ASME, 103, pp 725-730 (1981).

APPENDIX. DATA FOR VARIOUS COMPOSITES

Table 1. Boron-Fiber/Polymer Matrix Composites

Reference*	Target				Impactor			Test Method	
	Continuous Fiber	Matrix	Geometrical Lay-up	Specimen Size (cm)	Material and Type	Size	Impact Velocity (m/sec)	Type	Variables, objectives, observations, conclusions, etc.
B-1	Boron	Epoxy/5505	$(0/\pm45)s$			30 caliber and	365.8,838.2		Variables: lamination sequence,
			$(0/\pm45/90)s$	15x15		50 caliber	914.4	ballistic	impactor.
			$(0/\pm60)s$						
B-2	Boron	Epoxy	$[(\pm45)_4/0_8]s$	22.9x5.1x0.25	gelatin,ice	1.27,2.54cm dia	152,213,274	spin test	Variables: ply configuration,
			$[(\pm45)_2/0_6]s$	(flat plate)	steel balls	0.64,1.2cm dia	61,122	ballistic	fiber content, specimen thickness
B-3	Boron	Epoxy		81x23.4x(0.7 -	ice balls	5.1 cm dia	216.0	spin test	damage threshold 45-135g, max.strain
				1.8)	gravel and	0.6cm dia			recorded angle of impact 30°
					gelatin	160 gm			
B-4	Boron-	Epoxy	$[(\pm45_2)/+90_2/+45$	40-48(blade	gravel	0.6 cm dia			measurements with high speed
	Titanium		$/+90_2/-45/+90_2$	length)	steel bolts	0.3 cm		spin test	photography.
	core shells		$/+45/90_2]s$		& rivets				
	spar				ice balls	5.1 cm dia		spin test	
					gelatin	454 gm,909 gm			
					birds	499 gm			
B-5	Boron	Epoxy/PR-288	[0/+22/0/-22]		ice balls	5.1 cm dia.		spin test	measurement techniques: damage scan,
					gravel	0.4-0.6 cm dia			strain gages, accelerometers, high speed
					gelatin	7.6-10 cm dia.			moire, c-scan, holography, dye-penetrant.
					birds	450 gm			
B-6	Boron	Epoxy/5505	$(0/\pm45_2/0)s$		projectiles	30 caliber	381, 838	ballistic	objectives: to establish threshold
			$(0_2/\pm45/0/90)s$	55.8x20.3					strength and residual strength.
			$(0/\pm60_2/0)s$		projectiles	50 caliber	914.4		
B-7	Boron	Epoxy/PR-288			gelatin	170,340,595 gm		spin test	Variable: impactor.
							244	cross head	
					gravel	0.4-0.9 cm dia			
					ice balls	3-5 cm dia.			

*List of references follow tables.

Table 2. Chopped-Fiber Composites

Reference	Target				Impactor			Test Method	
	Chopped Fiber	Matrix	Geometrical Lay-Up	Specimen Size (cm)	Material and type	Size	Impact Velocity (m/sec)	Type	Variables, objectives, observations, conclusions, etc.
CH-1	Boron	Epoxy	(Unidirectional with fiber lengths 0.64, 1.27,1.9,5.1cm)	5.5x1.0x0.5	steel pendulum			Charpy	Conclusion: toughness is maximum for fibers close to critical l/d ratio.
CH-2	E-glass	Polyster	(SMC-R50)	25.4x25.4x0.23 (flat plate)	steel ball	0.64,127 cm dia	2.8	pendulum (ball attached to string)	Measurements: strain histories at various locations measured and compared with the finite element solutions.
CH-3	E-glass	Polyster	(SMC composite)	6.4 cm dia (circular plate)	steel hemisphere		0-4.4	drop weight	Variables: impactor size, specimen thickness, impact velocity.
CH-4	E-glass	Polyster	(SMC-R50)	7.6x1.27x0.36 (beam)	steel pendulum		4.9	Charpy	Objective: effect of temperature on the impact energy.
CH-5	E-glass	Polyster	(SMC-R35)		steel ball	2.2 cm dia		gas-gun	Measurements: the dent depth using shadow moire, the surface damage using radiographic, ultrasonic and crack ennancement techniques.
CH-6	E-glass	Polyster	(SMC-R50) (SMC-R65)	15x15x0.24 15x15x0.27	steel cylinder (blunt-ended)	0.97 cm dia, 2.54 cm length	30-83.5 30-94.5	gas-gun	Measurements: damage zone size, residual tensile stength and stiffness. Modeling: a fracture mechanics model to assess the residual tensile strength

Table 3. Glass-Fiber Composites

Reference	Target: Continuous Fiber	Target: Matrix	Target: Geometrical Lay-Up	Target: Specimen Size (cm)	Impactor: Material and Type	Impactor: Size	Impactor: Impact Velocity (m/sec)	Test Method: Type	Test Method: Variables, objectives, observations, conclusions, etc.
GL-1	S-glass	Epoxy/ERL2256	(unidirectional)	3.8x0.8x0.8	Steel		3.5	Izod	
GL-2	Glass	Epoxy/5206	(0/±45)s	15x15	projectile	30caliber	366.0 and 838.0	gas-gun	Variables: lamination-sequence
			(0/±45/90)s	(flat plate)		50caliber	914.0		
			(0/±60)s					Izod and	Variables: type of specimens
GL-3	S-glass	Epoxy						Charpy	(notched and unnotched)
GL-4	Glass	Epoxy		81x23.4x(0.7-	ice balls	5.1cm dia.	216.0	Spin test	Variables: angle of impact and
				1.8)(flat plate)	gravel	0.6cm dia.			impactors. Observations: damage-
					gelatin	160 gm			threshold is 40-105 g.
GL-5	Glass	Epoxy/PR-288	[0/+22/0/-22]		ice balls	5.1cm dia.		Spin test	Measurement techniques: damage
					gravel	0.4-0.6cm dia.			scan, strain gages, accelerometers,
					gelatin	7.6-10 cm dia.			high-speed moire, c-scan, holography
					birds	450 gm			and dye penetrant.
GL-6, GL-8	Glass	Epoxy/E-828	(90/0/90/0/90/0/90/0)s	15x15(flat plate)	steel cylinder(blunt	0.97cm dia.	135.0-199.0	ballistic	Variable: Stacking sequence.
			$(90_3/0_3/90_3/0_3/90_3)$			2.54cm			Conclusion: Stacking sequence is
			$(90_5/0_5/90_5)$		and conical	length			very important in affecting the
			$(90_8/0_7),(0_{15})$		ends)				fracture pattern.
			$(90/0_2/90_3/0_4/90_5)$						
GL-7	S-glass	Epoxy/PR-288			ice ball	3-5cm dia.	244.0	Spin test and	Variables: impactors
					gravel	0.4-0.9cm dia.		cross head	
					gelatin	170,340 & 595gm			
GL-9, GL-11	E-glass	Epoxy/E-828	$(0/90/0/\text{---})_{15}$	15x15x0.6	steel cyl-	0.97cm dia.	46.0-137.0	gas-gun	Observations: generator strip
			(cross ply, 15	(flat plate)	inder(blunt	and 2.54			formation, sequencial delamination
			different stacking		ended nose)	cm length			mechanism and matrix cracks were
			sequence)						found the principal failure mecha-
									nisms. The delamination mechanism
									was found to be the dominant
									energy absorption mechanism.

Table 3 (cont'd)

GL-10	Glass	Epoxy/E-828 Polyester/P-43		12 x 6.3 (beam)				Charpy	Variables: interface strength by varying glass surface treatment
GL-12	E-glass	Epoxy/1003	$(0_5/90_5/0_5)$ $(+15_5/-15_5/+15_5)$ $(+30_5/-30_5/+30_5)$	15x15x0.35 (flat plate)	Steel cylinder(blunt ended and hemispherical nose)	0.97cm dia. 2.54 and 5.1 cm length	30.0-80.0	gas-gun	Conclusions: The total delaminated area has been found to be linearly related to impactor kinetic energy. Hemispherical nose produces more local crushing and less developed generator strip than does a blunt nose.
GL-13	E-glass	Epoxy/1003	$(0_5/90_5/0_5)$ $(+30_5/-30_5/30_5)$	15x15x0.35 (flat plate)	steel cylinder(blunt-ended nose)	0.97cm dia. 2.54cm length	30.0-40.0	gas-gun	Measurement: Dynamic strains using surface and embedded strain gages. Conclusions: The largest-amplitude flexural waves appeared the most important factor causing the delamination fracture.
GL-14	E-glass	Epoxy/1003	$(0_5/90_5/0_5)$	15x15x0.35 (flat plate)	steel clinder(blunt ended nose)	0.97cm dia. 2.54 and 5.1 cm length	50.0-83.0	gas-gun	Measurements: Delamination crack propagation velocity using high speed camera, generator-strip formation velocity.
GL-15	E-glass	Epoxy	$[30_5/\phi_5/30_5]$ with ϕ=0,-15,-30, -45&-60° $[\theta_5/(90-\theta)_5/\theta_5]$ with θ=0,15,30 & 45°	15x15x0.35 (flat plate)	steel cylinder(blunt-ended)	0.97cm dia. and 2.54cm length	0-310.0	gas-gun	Conclusions: Residual stiffness reduction is much less than the strength reduction. Artificial delamination of the same shape and size as that of impact-induced delaminations produces correlative stiffness and strength reduction.
GL-16	S2-glass	Epoxy/3501-6	(unidirectional)	1.3,5.1 and 8.9(gage length)	steel		2.7,3.4,3.8, 4.5 and 4.9	Izod and Charpy	Failure Modes: delamination and matrix cracking

Table 4. Graphite or Carbon-Fiber Composites

Ref.	Target				Impactor			Test	
	Continuous Fiber	Matrix	Geometrical Lay-Up	Specimen Size (cm)	Material and type	Size	Impact Veclocity (m/sec)	Type	Variables, objectives, observations, conclusions, etc.
GR-1	Thornel 50S-Graphite								
	Thornel 50-Graphite								
	HTS-Graphite								
	Modmor I-Graphite	Epoxy/ERL-2256	(unidirectional)	3.8x0.8x0.8	steel pendulum		3.45	Izod	
	HTS/Thornel 50S-Graphite								
	HMS/Modmor I-Graphite								
	HMS/Graphite								
GR-2	Thornel 50-Graphite	Epoxy/ERL-2256	$[0/+45/-45/90]_s$	23x23x0.65 (flat plate)	steel projectile			ballistic	Observations: fracture and failure mechanisms, energy dissipation mechanisms.
GR-3	Thornel 50S-Graphite	Epoxy/5206	$(0/\pm45)_s$ $(0/\pm45/90)_s$ $(0/\pm60)_s$	15x15 (flat plate)	steel projectile	30 caliber and 50 caliber	365.8,838.2 914.4	ballistic	Variables: impactor, impact velocity, lamination sequence.
GR-4	T505-Graphite							Izod	Observations: fiber failure
	HTS-Graphite	Epoxy						Charpy	modes.
	HMS-Graphite								
GR-5	Modmor I-Graphite	Epoxy	$[(0/+30/0/-30/0)_2]_s$	23x5.1x0.25	steel ball	0.64 cm dia.	61,91,122	spin test,	Variables: impactor, fiber
	Modmor II-Graphite	Epoxy/PR-286	$[(\pm45)_2/0_{12}/\mp45)_2]_T$	(flat plate)	steel ball	1.27 cm dia.	31,61,91	ballistic	type, ply-con-
	T-75-S-Graphite	Epoxy	$[(\pm45)_4/0_8]_s$		ice ball	1.27 cm dia.	61,107,152		figuration, fiber-content,
	Modmor II-Graphite	Polyimide	$[(\pm45)_3/0_6/0]_s$		ice ball	2.54 cm dia.	213,274,305		specimen thickness. Impact
					gelatin ball	2.54 cm dia.	67,101,152		models: Hertz, modified
					gelatin ball	1.27 cm dia.	152,213,274		Hertz and impulse.
GR-6	Thornel 50 S-Graphite	Epoxy/5206	$(0/\pm45/0)_s$ $(0_2/\pm45/90)_s$ $(0_2/\pm60_3/0_2)_s$	55.8x20.3 (flat plate)	steel projectile	30 caliber 50 caliber	381 and 838 914.4	ballistic	Objectives: to establish threshold strength and residual strength.
GR-7	Graphite	Epoxy/5505			gelatin	170,340,595 gm	244	spin test	Variables: fibers
	Au-Graphite	Epoxy/PR-288			ice ball	3-5 cm dia.		cross-head	and impactors
					gravel	0.4 to 0.9 cm dia.			

Table 4 (cont'd)

GR-8	HTS-Graphite	Epoxy/ERL-2256	$[0/90]_{3s}$, $[\pm 45]_{3s}$ $[0/\pm 45/90/\mp 45/0]_s$	20.3x1.9x0.32 (cantilever beam)	steel pendulum			Charpy	Observations: failure modes. Varible: angle of impact.
GR-9	Graphite	Epoxy/5206 (Modulite)	$[0_2/\pm 45/0_2/90/0_2/\mp 45/0_2]_{4T}$	5.5x1.0x0.74				Charpy	Variable: Specimen orientation. Longitudinal: more 0-plies. Transverse: less 0-plies.
GR-10	Graphite	Epoxy			hardened steel	50 caliber	498, 517	ballistic	Variable: impact angle 60°, 90°
GR-11 GR-13	Thornel 300-Graphite	Epoxy/5208	$[\pm 45/0_2/\pm 45/0_2/\pm 45/0/90]_{2s}$	24.8x11.4 (flat plate)	aluminum ball	1.27 cm dia.	52-101	gas-gun	Objective: effect of impact damage and circular holes on compressive strength.
GR-12	Graphite	Epoxy		(flat plate)	steel projectile	50 caliber	448	ballistic	Variable: angle of impact.
GR-14	Thornel 300-Graphite	Epoxy/SP-313	(unidirectional)					Charpy	Variable: specimen size.
GR-15	HTS-Carbon	Epoxy/DX 210	$(0/90/0/\pm 45/0)_s$	6x2.5x0.2	steel ball	0.6,1.25 cm dia.	(0-20 J, impact energy)	gas-gun	Measurements: Delaminated areas, residual strengths in tension, flexural and shear.
GR-16	AS-graphite	Epoxy/3501	$(\pm 45/0/90)_s$		steel hemi-spherical ball	1.6 cm dia., 240 gm wt.	(drop height 0.6 to 2.9 m)	drop weight	
GR-17	Celion GY70-Graphite Modmor II-Graphite Thornel 300-Graphite	Epoxy/5208 Epoxy/5208 Epoxy/5208	$[(0/-60/+60)4]_s$ $[0]_{24}$, $[0/90)_6]_s$ $[(0/-60/60)/(0/60/-60)_3]_s$		steel ball	3.8 cm dia.	1.2-4.9	drop weight	Variables: Fiber types, Fiber orientation, stacking sequence, plate thickness, impact velocity.
GR-18	Thornel 300-Graphite	Epoxy/5208	(flat plate)		aluminum ball	1.27 cm dia.	55	gas-gun	Variable: axial compression
GR-19 GR-26	Thornel 300-Graphite	Epoxy/5208	$(\pm 45/0_2/\pm 45/0_2/\pm 45/0/90]_{2s}$ $(\pm 45/0/90/\mp 45/0/90]_{3s}$ $(45/0-90)_{5s}$ $[\pm 45/0_4/\mp 45/\pm 45/0_4/\mp 45/\pm 45/0_2]_s$	12.7x12.7 to 38x25	aluminum ball	1.27 cm dia.	30-140	gas-gun	Objectives: to identify failure mechanisms, to understand damage propagation in compression loaded structures.
GR-20	HTS-Carbon	Epoxy	(unidirectional)	5.0x0.63x0.16 (beam)	steel pendulum	0.05 cm (tip-diameter)	(0-4J impact energy)	drop weight	Variables: Width and thickness of the specimens, impacting wedge bluntness, and the angle of impact. Observations: SEM and cinephotography to study cracking.

Table 4 (cont'd)

GR-21	Graphite	24 different resins	$[\pm45/0_2/\pm45/0_2/\pm45/0/90]_{2s}$	25.4x12.7	aluminum ball	1.27 dm dia.	0-100		Variable: resin system
GR-22	Carbon	Epoxy/5208	$[0/90/0\text{---}]_{27}$ $[0_9/90_9/0_9]$	15x15x0.35 (flat plate)	steel cylinder (blunt-ended nose)	0.97 cm dia. and 2.54 cm length	150,178	ballistic	Measurements: load-deflection characteristics and residual flexural strength of the impacted specimens.
GR-23	Thornel 300-Graphite	Epoxy/5208	$[45/0/-45/90]_s$	15x10 (flat plate)	steel ball	0.95,1.6,2.54 cm dia.	10	drop weight	Measurements: impact damage area, threshold impact energy, residual tensile strength.
GR-24	AS-Graphite	Epoxy/3501-6	$(\pm45/0_2)_2/\pm45/0/90]_{2s}$	steel impactor	0.32 to 5 cm tip-diameter				Variable: impactor tip diameter.
GR-25	Thornel 300-Graphite	Epoxy/5208			aluminum ball	2.54 cm dia.	0.1-10.0	drop weight	
GR-27	Thornel 300-Graphite	Epoxy/5208 polysulfone/P1700	$(45/0/-45/90)_s$	1.27 to 7.0 cm dia. disks	steel ball		10-50	drop weight	Variables: specimen size and matrix material.
GR-28	AS-graphite	Epoxy/3501-6	(unidirectional)	(gage length 1.3, 5.1 and 8.9)	steel pendulum		2.7,3.4,3.8 4.5 and 4.9	Izod and Charpy	Observations: large scale failures in fibers.

Table 5. Hybrid Composites

Reference	Target: Continuous Fiber	Target: Matrix	Target: Geometrical Lay-Up	Target: Specimen Size (cm)	Impactor: Material and Type	Impactor: Size	Impactor: Impact Velocity (m/sec)	Test Method: Type	Test Method: Variables, objectives, observations, conclusions, etc.
H-1	HTS-carbon/E-glass	Epoxy/DX-210 Epoxy/ERLA 4617	50% C+50% G (sandwich)	30x1.3x0.25 (unnotched beam)			2.5	Izod	Variables: glass and carbon content. failure modes: delamination, resin shattering and complete failure. Conclusion: glass inclusion increases the impact energy 2.5 to 5 times.
H-2	Modmor II graphite/s-glass(20%)	Epoxy/PR-286	(0/±22)s		gelatin balls	1.3,2.6 and 5.1 cm dia.	90,150,245 and 275	gas-gun and charpy	Effect of ply orientation and composition, effect of projectile mass and specimen thickness.
	Modmor II graphite/S-glass(40%)	Epoxy/PR-286	(0/90/±45)s						
H-3	AU-Graphite/S-glass	Epoxy/PR 288	(0/22/0/-22)		gelatin bird	87,227,680gm 567 gm	244	ballistic, spin test	Variable: Fibers
	AU-Graphite/kevar 49	Epoxy/PR 288							
H-4	Carbon/E-glass	Polyester	(rods, notched and unnotched)					Charpy	Variables: Fiber content. Conclusions: work of fracture is a mixture rule for notched samples.
H-5	Graphite/glass fabric	Epoxy/5206	$(0/0^t/\pm45/0^t/0_2/90/0_2/0^t/\pm45/0^t/0)$					Charpy (notched specimen)	
	Graphite/Aluminum mesh	Epoxy/5206	t:third phase						
	Graphite/Titanium foil	Epoxy/5206							Tests: tensile, short beam shear.
	Graphite/S_2-glass	Epoxy/5206							
H-6	AU-Graphite/S-glass/Boron/Kevlar	Epoxy	(0±45)						
	AS-Graphite/S-glass/Boron/Kevlar	Epoxy	(0±45)						
	AS-Graphite/S-glass/Boron	Epoxy	(0±45)		gelatin	14-28 gm		ballistic	Objectives: to design, fabricate,
	80AS-Graphite/20 S-glass	Epoxy	(0±35)					and	and test QCSEE type fan blades.
	80AS-Graphite/20 S-glass/boron	Epoxy	(0±35)					Charpy	
	T-300 Graphite/S-glass	Epoxy	(0±35)						
H-7	HTS-carbon/PRD-49 kevlar	$[(0_k/90_k/0_c/\pm45_c/0_c)]s$ $[(0_c/90_c/0_c/\pm45_k/0_c)]s$	6x2.5x0.2	steel ball steel ball	0.6 cm dia. 1.3 cm dia.			gas-gun drop weight	Measurements: Delaminated areas residual strengths in tension, flexural and shear. Conclusions: kevlar increases impact strength significantly.

Table 6. Kevlar-Fiber Composites

Reference	Target				Impactor			Test Method	
	Continuous Fiber	Matrix	Geometrical Lay-Up	Specimen Size (cm)	Material and Type	Size	Impact Velocity (m/sec)	Type	Variables, objectives, observations, conclusions, etc.
K-1	Kevlar	Epoxy/ERL-2256	(Unidirectional)	3.8x0.8x0.8	steel pendulum		3.45	Izod	
				(beam)					
K-2	Kevlar	Epoxy			steel pendulum			Izod, Charpy	Specimens: unnotched and notched
									Observations: fiber failure modes
K-3	Kevlar	Epoxy/PR 286	$[(\pm45)_2/0_6]_s$	23x5.1x0.25	ice ball	1.27 cm dia.	260-280	ballistic	Variables: stacking sequence,
			$[0_{20}]$,	(flat plate)					fiber orientation.
			$[(\pm45)_4/0_8]_s$						Impact Models: Hertz, modified
									Hertz and Impulse.
K-4	Kevlar	Epoxy/PR 288			gelatin	170,340,595gm		spin test	Variables: impactors.
					ice ball	3-5 cm dia.		cross head	
					gravel	0.4-0.9 cm dia.			
K-5	Kevlar	Epoxy/DX 210	$(0/90/0/\pm45/0)_s$	6x2.5x0.2	steel ball	0.6 cm dia.		gas-gun	Measurements: Delaminated
				(beam)	steel ball	1.3 cm dia.	0-20J(impact energy)	drop weight	areas, residual strengths in tension,
									flexural and shear.
K-6	Kevlar	Epoxy	$(0/90/0\text{---})_{17}$	15x15x0.35	steel cylinder	0.97 cm dia.	150,250	gas-gun	Measurements: Load-deflection
			$(0_6/90_6/0_6)$	(flat plate)	(blunt-ended nose)	and 2.54 cm length	112,150		characteristics, residual strength and stiffness.

Table 7. Metal Matrix Composites

Reference	Target				Impactor			Test Method	
	Fiber	Matrix	Geometrical Lay-Up	Specimen Size (cm)	Material and Type	Size	Impact Velocity (m/sec)	Type	Variables, objectives, observations, conclusions, etc.
MM-1	Aluminum	Al_3Ni						Charpy and	Observations: Fracture and crack
	Aluminum	Al_2Cu						Izod	growth behavior was observed.
	Ni_3Al	Ni_3Nb							
	Co	$Cr-(Co,Cr)_7C_3$							
MM-2	Boron	Aluminum/2024	(8ply specimens)		steel sphere	0.44 cm dia.	304.8	gas-gun	
		Aluminum/6061							
MM-3	Al alloys	Aluminum/1100			Projectiles	50 caliber		ballistic	
	(ceramic Armor)	Aluminum/6061			pebble		305-1830	and plate	
	(ceramic Armor) with graphite backing	Aluminum/7075			steel balls, gelatin			slap	
MM-4	Boron	Aluminum/6061		10.8x2.54x0.14	steel balls	0.45 cm dia.	33.5-341.4	gas-gun	Tests: ultimate tensile strengths
		Ti-6Al-4V		15.2x2.54x0.17			266-807		vs K.E. of impact, tensile pre-stress on the specimens. Other Tests: NDT, tensile and tensile fatigue tests on the impacted specimens.
MM-5	Borsic filaments (spar-shell type with titanium spar)	Aluminum/6061	(fan blade of QCSEE type)		ice ball gelatin bird	5.1 cm dia. 300,700,1400gm 1126,1203 gm			NDE: X-Ray, and holography.
MM-6	Boron	Aluminum/2024	(unidirectional)		steel cylinder			Charpy and	Variables: notched and unnotched
	Borsic	Aluminum/6061	±15°,±22°,±45°			0.8 cm dia.		Ballistic	specimens. Damage assessed by
	Borsic/Ti	Aluminum/1100				0.8 cm long			visible crack or fracture of
	Hybrids Al/Ti								specimens. Measurements: Local
MM-7	Boron	Aluminum/6061						gas-gun	damage, post-impact properties.
					steel sphere			drop weight	
				10.2x1.0			0-1200		B/Al: no degradation in residual
				(cantilever	RTV-11 rubber				tensile strength at Vel.<460 m/sec.
				beam)	sphere				
MM-8		Ti-6Al-4V			Steel projectile	50 caliber	300-500	Ballistic	Variables: angle of impact, residual
	Boron	Aluminum						& chemical propalent impact	momentum.

Table 7 (cont'd)

MM-9	Boron	Aluminum			projectile	50 caliber	448	ballistic	Variables: normal and oblique impact.
	Titanium	6Al-4V	(plates)						Observations: Brittle behavior of target
	Titanium -T6	Aluminum/6061							reduces momentum transfer.
MM-10	Boron	Aluminum/1100	(unidirectional)					Charpy	Variables: Size effect.
	Boron	Aluminum/6061							
MM-11	Boron	Titanium			hard particles	0.05-0.32 cm	120-490	gas gun	Variables: Impactor material and size.
	Boron	Ti8Al-1 Mo-1V			chrome spheres	diameter			Tests: Measurement of fatigue strength.
					pyrex, glass spheres and sand				
MM-12	Boron	Pure Al/1200			steel, hemisphere	0.6 cm dia.		indentation	Variable: impact velocity.
		Aluminum/2024	(unidirectional)		steel cylinder	0.5 cm dia. 1.2 cm length	$2x10^{-6}$-4.0	ballistic	Conclusions: No delamination of the matrix. Fibers failed by bending forces under the impactor at the center.
MM-13	Titanium,T6	Aluminum/7075	(cantilever beam)		gelatin	1.3,1.8,2.6 and 3.2 cm dia.	91.5-106.7	ballistic	Analysis: Timoshenko beam model.
MM-14	Ti-core and Ti-com spar shell (design CF6 type blade)				bird	80,81,85 and 255 gm		spin test	Conclusions: Ti-core blade proved to be of superior design from a bird impact resistance standpoint.

Table 1. Boron-Fiber/Polymer Matrix Composites

B-1. Olster, E.F. and Woodbury, H.A., "Evaluation of Ballistic Damage Resistance and Failure Mechanisms of Composite Materials," AFML-TR-72-79 (Apr 1972).

B-2. Friedrich, L.A. and Preston, J.L., Jr., "Impact Resistance of Fiber Composite Blades Used in Aircraft Turbine Engines," NASA CR-134502 (May 1973).

B-3. Premont, E.J. and Stubenhauch, K.R., "Impact Resistance of Composite Fan Blades," NASA CR-134515 (May 1973).

B-4. Graff, J., Stoltze, L., and Varholak, E.M., "Impact Resistance of Spar-Shell Composite Fan Blades," NASA CR-134521 (July 1973).

B-5. Steinhagen, C.A. and Salemme, C.T., "Impact Resistance of Current Design Composite Fan Blades Tested under Short-Haul Operating Conditions," NASA CR-134533 (July 1973).

B-6. Olster, E.F. and Roy, P.A., "Tolerance of Advanced Composites to Ballistic Damage," Composite Materials: Testing and Design, STM STP 546, pp 583-603 (1974).

B-7. G.E.C. Aircraft Engine Group, "Impact Resistance of Composite Fan Blades," NASA CR-134707 (Dec 1974).

Table 2. Chopped-Fiber Composites

CH-1. Allred, R.E. and Schuster, D.M., "The Impact Toughness of Discontinuous Boron-Reinforced Epoxy Composites," J. Matls. Sci., 8 (2), pp 245-250 (1973).

CH-2. Sun, C.T., Sankar, B.V., and Tan, T.M., "Dynamic Response of SMC to Impact of a Steel Ball," Advances in Aerospace Structures and Materials, S.S. Wang and W.J. Renton, Eds., Vol. AD-01, pp 99-107, ASME (1981).

CH-3. Myers, F.A., "Impact Behavior of SMC Composites," Paper No. 1-D, Pres. at 37th Ann. Conf., Soc. Plastics Indus. (SPI), Washington, D.C. (Jan 11-15, 1982).

CH-4. Hughes, H., Puig, J., and Beatty, C.L., "Impact Properties of SMC," Proc. Natl. Tech. Conf. (SPE), Bal Harbour, FL, pp 63-64 (Oct 25-27, 1982).

CH-5. Khetan, Raghunath, P. and Chang, David, C., "Surface Damage of Sheet Molding Compound Panels Subject to a Point Impact Loading," Proc. 19th Ann. Mtg., Soc. Engrg. Sci., p 42 (1982).

CH-6. Chaturvedi, S.K. and Sierakowski, R.L., "Residual Strength Assessment of SMC Composites Subjected to Dynamic Impact," Natl. Engrg. Mech. (ASCE) Specialty Conf., May 23-25, 1983, Purdue Univ.; to be published in Composite Structures.

Table 3. Glass-Fiber Composites

GL-1. Chamis, C.C., Hanson, M.P., and Serafini, T.T., "Designing for Impact Resistance with Unidirectional Fiber Composites," NASA TN D-6463 (Aug 1971).

GL-2. Olster, E.F. and Woodbury, H.A., "Evaluation of Ballistic Damage Resistance and Failure Mechanisms of Composite Materials," AFML-TR-72-79 (Apr 1972).

GL-3. Chamis, C.C., Hanson, M.P., and Serafini, T.T., "Impact Resistance of Unidirectional Fiber Composites," Composite Materials: Testing and Design, ASTM STP 497, pp 324-349 (1972).

GL-4. Premont, E.J. and Stubenhauch, K.R., "Impact Resistance of Composite Fan Blades," NASA CR-134515 (May 1973).

GL-5. Steinhagen, C.A. and Salemme, C.T., "Impact Resistance of Current Design Composite Fan Blades Tested under Short-Haul Operating Conditions," NASA CR-134533 (July 1973).

GL-6. Ross, C.A. and Sierakowski, R.L., "Studies on the Impact Resistance of Composite Plates," Composites, 4, pp 157-161 (July 1973).

GL-7. G.E.C. Aircraft Engine Group, "Impact Resistance of Composite Fan Blades," NASA CR-134707 (Dec 1974).

GL-8. Cristescu, N., Malvern, L.E., and Sierakowski, R.L., "Failure Mechanisms in Composite Plates Impacted by Blunt-Ended Penetrators," Foreign Object Damage to Composites, ASTM STP 568, pp 159-172 (1975).

GL-9. Sierakowski, R.L., Malvern, L.E., and Ross, C.A., "Dynamic Failure Modes in Impacted Composite Plates," Failure Modes in Composites III, Editor T.T. Chiao, Amer. Inst. Mining, Metal. Petrol. Engrs., pp 73-88 (1976).

GL-10. Yeung, P. and Broutman, L.J., "The Effect of Glass-Resin Interface Strength on the Impact Strength of Fiber Reinforced Plastics," 1977 Reinforced Plastic Conf., Soc. Plastic Indus. (SPI) (Feb 1977).

GL-11. Malvern, L.E., Sierakowski, R.L., and Ross, C.A., "Impact Failure Mechanisms in Fiber Reinforced Composite Plates," High Velocity Deformation of Solids, IUTAM Symposium Tokyo/Japan, Aug 24-27, 1977, Kozo Kawata and Jumpei Shioiri, Eds., Springer-Verlag Berlin, Heidelberg, pp 120-131 (1979).

GL-12. Takeda, Nobuo, Sierakowski, R.L., and Malven, L.E., "Studies of Impacted Glass Fiber Reinforced Composite Laminates," SAMPE Quart., 12 (2), pp 9-17 (1981).

GL-13. Takeda, Nobuo, Sierakowski, Robert L., and Malvern, Lawrence E., "Wave Propagation Experiments on Ballistically Impacted Composite Laminates," J. Composite Matls., 15, pp 157-174 (1981).

GL-14. Takeda, N., Sierakowski, R.L., and Malvern, L.E., "Delamination-Crack Propagation in Ballistically Impacted Glass/Epoxy Composite Laminates," Exptl. Mech., 22 (1), pp 19-25 (1982).

GL-15. Sierakowski, R.L., Ross, C.A., Malvern, L.E., and Doddington, H.W., "Studies on the Fracture Mechanisms in Partially Penetrated Filament Reinforced Laminated Plates," Tech. Rept. No. 1, U.S. Army Res. Off. (DAAG 29-79-G-007) (Jan 1982).

GL-16. Hayes, S.V. and Adams, D.F., "Rate Sensitive Tensile Impact Properties of Fully and Partially Loaded Unidirectional Composites," J. Test. Eval. (ASTM), 10 (2), pp 61-68 (1982).

Table 4. Graphite or Carbon-Fiber Composites

GR-1. Chamis, C.C., Hanson, M.P., and Serafini, T.T., "Designing for Impact Resistance with Unidirectional Fiber Composites," NASA TN D-6463 (Aug 1971).

GR-2. Askins, D.R. and Schwartz, H.S., "Mechanical Behavior of Reinforced Plastic Backing Materials for Composite Armor," AFML-TR-71-283 (Feb 1972).

GR-3. Olster, E.F. and Woodbury, H.A., "Evaluation of Ballistic Damage Resistance and Failure Mechanisms of Composite Materials," AFML-TR-72-79 (Apr 1972).

GR-4. Chamis, C.C., Hanson, M.P., and Serafini, T.T., "Impact Resistance of Unidirectional Fiber Composites," Composite Materials: Testing and Design, ASTM STP 497, pp 324-349 (1972).

GR-5. Friedrich, L.A. and Preston, J.L., Jr., "Impact Resistance of Fiber Composite Blades Used in Aircraft Turbine Engines," NASA CR-134502 (May 1973).

GR-6. Olster, E.F. and Roy, P.A., "Tolerance of Advanced Composites to Ballistic Damage," Composite Materials: Testing and Design, ASTM STP 546, pp 583-603 (1974).

GR-7. G.E.C. Aircraft Engine Group, "Impact Resistance of Composite Fan Blades," NASA CR-134707 (Dec 1974).

GR-8. Yew, C.H. and Benedict, B.K., "Fracture of Fiber-Reinforced Beams due to Impact Loading," BRL Contract Rept. No. 212 (Mar 1975).

GR-9. Adams, D.F. and Perry, J.L., "Low Level Charpy Impact Response of Graphite/Epoxy Hybrid Composites," J. Engr. Matl. Tech. (1975).

GR-10. Barber, J.P. and Taylor, H.R., "Ordnance Impacts on Jet Engine Fan Blades," AFML-TR-76-34 (Apr 1976).

GR-11. Rhodes, M.D., Williams, J.G., and Starnes, J.H., "Effect of Impact Damage on the Compression Strength of Filamentary-Composite Hat-Stiffened Panels," Materials and Process Engineering Series, Vol. 23: Selective Application of Materials for Products and Energy, pp 300-319 (1978).

GR-12. Rosenblatt, M., Isbelle, T.R., Fry, P.F., Barber, J.P., and Taylor, H.R., "Investigation of Local Damage and Impulse Delivered to Turbine Blocks by Normal and Oblique Projectile Impacts," AFML-TR-76-208 (Jan 1977).

GR-13. Rhodes, M.D., Williams, J.G., and Starnes, J.H., "Effect of Low-Velocity Impact Damage on the Compressive Strength of Graphite-Epoxy Hat-Stiffened Panels," NASA TN D-8411 (Apr 1977).

GR-14. Krinke, D.C., Barber, J.P., and Nicholas, T., "The Charpy Impact Test as a Method for Evaluating Impact Resistance of Composite Materials," AFML-TR-78-54 (Apr 1978).

GR-15. Dorey, G., Sidey, G.R., and Hutchings, J., "Impact Properties of Carbon Fiber/Kevlar 49 Fiber Hybrid Composites," Composites, 9, pp 25-32 (1978).

GR-16. Aleszka, J.C., "Low Energy Impact Behavior of Composite Panels," J. Test Eval. (ASTM), 6 (3), pp 202-210 (1978).

GR-17. Greszczuk, L.B. and Chao, H., "Impact Damge in Graphite-Fiber Reinforced Composites," Composite Materials: Testing and Design (Fourth Conf.), ASTM STP 617, pp 389-408 (1977).

GR-18. Starnes, J.H., Rhodes, M.D., and Williams, J.G., "The Effect of Impact Damage and Circular Holes on the Compressive Strength of a Graphite-Epoxy Laminate," NASA TM 78796 (Oct 1978).

GR-19. Rhodes, M.D., Williams, J.G., and Starnes, J.H., "Low-Velocity Impact Damage in Graphite-Fiber Reinforced Epoxy Laminates," Proc. 34th Ann. Conf. Reinforced Plastics/Composite Inst., Soc. Plastics Indus., New Orleans, LA (Jan 29 - Feb 2, 1979).

GR-20. Butcher, B.R., "The Impact Resistance of Unidirectional CFRP under Tensile Stress," Fibre Sci. Tech., 12, pp 295-326 (1979).

GR-21. Williams, J.G. and Rhodes, M.D., "The Effect of Resin on the Impact Damage Tolerance of Graphite-Epoxy Laminates," NASA TM 83213 (Oct 1981).

GR-22. Sierakowski, R.L., Ross, C.A., Malvern, L.E., and Doddington, H.W., "Studies on the Fracture Mechanisms in Partially Penetrated Filament Reinforced Laminated Plates," Tech. Rept. No. 1, U.S. Army Res. Off. (DAAG 29-79-G-007) (Jan 1982).

GR-23. Lal, K.M., "Prediction of Residual Tensile Strength of Transversely Impacted Composite Laminates," Res. Struc. Solid Mech. - 1982, NASA Conf. Publ. 2245, pp 97-111 (1982).

GR-24. Ramkumar, R.L. and Chen, P.C., "Low Velocity Impact Response of Laminated Plates," AIAA/ASME SDM Mtg., New Orleans, pp 352-357, Paper No. 82-0750 (1982).

GR-25. Elber, Wolf, "Captive Ball Impact Studies: Methods, Analysis and Results for Graphite-Epoxy Plates," Proc. Seventh Ann. Mech. Composites Rev., AFWAL-TR-82-4007, pp 54-65 (Apr 1982).

GR-26. Starnes, J.H., Jr. and Williams, J.G., "Failure Characterization of Graphite-Epoxy Structural Components Loaded in Compression," NASA TM 84552 (Sept 1982).

GR-27. Illg, Walter, "Summary of Impact," Proc. Eighth Ann. Mech. Composites Review, AFWAL/Matls. Labs., Flight Dynam. Labs., AFOSR, NASA/Langley Lewis Ctrs., and Naval Air Devel. Ctr. (Oct 1982).

GR-28. Hayes, S.V. and Adams, D.F., "Rate Sensitive Tensile Impact Properties of Fully and Partially Loaded Unidirectional Composites," J. Test Eval. (ASTM), 10 (2), pp 61-68 (1982).

Table 5. Hybrid Composites

H-1. Hancox, N.L. and Wells, H., "Izod Impact Properties of Carbon-Fiber/Glass-Fiber Sandwich Structures," Composites, 4 (1), pp 26-30 (1973).

H-2. Friedrich, L.A., "Impact Resistance of Hybrid Composite Fan Blade Materials," NASA CR-134712 (May 1974).

H-3. G.E.C. Aircraft Engine Group, "Impact Resistance of Composite Fan Blades," NASA CR-134707 (Dec 1974).

H-4. Harris, B. and Bunsell, A.R., "Impact Properties of Glass-Fiber/Carbon-Fiber Hybrid Composites," Composites, 6, pp 197-201 (1975).

H-5. Perry, J.L., Adams, D.F., and Miller, A.K., "Effect of Low Level Impact on Advanced Hybrid Composites," Rept. Naval Air Syst. Command, Philco Ford Corp., Aerometronics Div., Newport Beach, CA (1975).

H-6. Oller, T.L., "Fiber Composite Fan Blade Impact improvement Program," NASA CR-135078 (Dec 1976).

H-7. Dorey, G., Sidey, G.R., and Hutchings, J., "Impact Properties of Carbon Fiber/Kelvar 49 Fiber Hybrid Composites," Composites, 9 (1), pp 25-32 (1978).

Table 6. Kevlar-Fiber Composites

K-1. Chamis, C.C., Hanson, M.P., and Serafini, T.T., "Designing for Impact Resistance with Unidirectional Fiber Composites," NASA TN D-6463 (Aug 1971).

K-2. Chamis, C.C., Hanson, M.P., and Serafini, T.T., "Impact Resistance of Unidirectional Fiber Composites," Composite Matls: Testing and Design, ASTM STP 497, pp 324-349 (1972).

K-3. Friedrich, L.A. and Preston, J.L., Jr., "Impact Resistance of Fiber Composite Blades Used in Aircraft Turbine Engines," NASA CR-134502 (May 1973).

K-4. G.E.C. Aircraft Engine Group, "Impact Resistance of Composite Fan Blades," NASA CR-134707 (Dec 1974).

K-5. Dorey, G., Sidey, G.R., and Hutchings, J., "Impact Properties of Carbon Fiber/Kevlar 49 Fiber Hybrid Composites," Composites, 9, pp 25-32 (1978).

K-6. Sierakowski, R.L., Ross, C.A., Malvern, L.E., and Doddington, H.W., "Studies on the Fracture Mechanisms in Partially Penetrated Filament Reinforced Laminated Plates," Tech. Rept. No. 1, U.S. Army Res. Off. (DAAG 29-79-G-007) (Jan 1982).

Table 7. Metal Matrix Composites

MM-1. Bibring, Herve, "Mechanical Behaviour of Unidirectionally Solidified Composites," Office National d'etudes et de Recherches Aerospatiales, Tire' A Part: T.P. No. 1147 (1972).

MM-2. Alexander, J.E. and Carlson, R.G., "Failure Processes in Metal Matrix Composites," AFML-TR-73-290 (1973).

MM-3. Lee, T.W., Swift, H.F., Preonas, D.D., Dueweke, P.W., and Berthe, R.S., "Response of Materials to Impulsive Loading," AFML-TR-73-45 (Feb 1973).

MM-4. Carlisle, J.G., "Hard-Body Impact Damage Effects on Boron-Aluminum Composites," Masters Thesis (Mar 1974).

MM-5. Graff, J., Stoltze, L., and Varholak, E.M., "Fiber Composite Fan Blade Impact Improvement," NASA CR-135001 (Feb 1976).

MM-6. Prewo, K., "Development of Impact Resistant Metal Matrix Composites," AFML-TR-75-216 (Mar 1976).

MM-7. Barber, J.P. and Taylor, H.R., "Response of Materials to Impulsive Loading," AFML-TR-76-17 (Mar 1976).

MM-8. Barber, J.P. and Taylor, H.R., "Ordnance Impacts on Jet Engine Fan Blades," AFML-TR-76-34 (Apr 1976).

MM-9. Rosenblatt, M., Isbelle, T.R., Fry, P.F., Barber, J.P., and Taylor, H.R., "Investigation of Local Damage and Impulse Delivered to Turbine Blocks by Normal and Oblique Projectile Impacts," AFML-TR-76-208 (Jan 1977).

MM-10. Krinke, D.C., Barber, J.P., and Nicholas, T., "The Charpy Impact Test as a Method for Evaluating Impact Resistance of Composite Materials," AFML-TR-78-54 (Apr 1978).

MM-11. Nicholas, T., Barber, John, and Bertke, Robert S., "Impact Damage of Titanium Leading Edges from Small Hard Objects," AFML-TR-78-113 (Nov 1978).

MM-12. Rich, G. and Bunsell, A.R., "The Behavior of Boron-Aluminum Composites during and after Impact," J. Matls. Sci., <u>14</u>, pp 2373-2383 (1979).

MM-13. Sharp, J.D., "Soft Body Impact of Cantilever Beams," AFML-TR-79-4169 (Mar 1980).

MM-14. Chamis, C.C., Lark, R.F., and Sinclair, J.H., "Super Hybrid Composite Blade Impact Studies," J. Engr. Power, Trans. ASME, <u>103</u>, pp 731-738 (1981).

BOOK REVIEWS

WAVE PROPAGATION THEORY

J.R. Wait
Pergamon Press, Elmsford, NY
1981, 348 pages

This work is not a book in the traditional sense of the word. Rather, as the full title, Lectures on Wave Propagation Theory, suggests, it is a selection of the author's papers on electromagnetic waves as they arise in various geophysical problems. The author, who is a Professor of Electrical Engineering and Geosciences at the Univeristy of Arizona, is clearly an expert.

There are 23 chapters in the book, too many to describe in detail. Among the major topics covered is the interaction of electromagnetic fields with the earth (magneto-telluric fields). Both horizontally and spherically stratified models, including some effects of anisotrophy, are discussed.

Such issues as the circumstances under which horizontal variations in field quantities can be neglected are raised. Zenneck and other interface waves are treated; the author shows that Zenneck wave illumination is not a good choice for enhancing ground wave field strength over a spherical earth. Another area covered in depth is transmission in crustal wave guides. Models involving continuously varying parameters (in the vertical direction) are also explored. The final sections deal with propagation in the atmosphere.

The prospective reader should have had a course on electromagnetic wave theory as well as considerable exposure to applied mathematics. The Lectures involve the topics: Fourier integrals and transforms, Fourier-Bessel transforms, saddle point methods for the asymptotic evaluation of integrals, Green's functions, Bessel, Legendre, Gamma and Airy functions and some of their asymptotic expansions, calculus of residues and contour integral modification techniques, and WKB methods including Langer's extension. In view of these somewhat formidable prerequisites I personally cannot recommend this book as a text, except perhaps in an advanced seminar setting. However, the work should be a welcome addition to a geophysicists library.

R.A. Scott
Professor
Department of Applied
and Mechanical Engineering
University of Michigan
Ann Arbor, MI 48109

PROCEEDINGS: NOISE AND THE ENVIRONMENT

National Board for Science and Technology
Dublin, Ireland
1980, 202 pages, 4 Irish pounds

This paperback book is the result of a seminar held in Ennis, County Clare, Ireland, during May, 1980, and organized by the National Board for Science and Technology of the Republic of Ireland. The objectives of the seminar were to review national and international research and technology of noise, to evaluate the various sources of noise, to assess the impact of noise on health, to examine abatement mechanisms as well as legislation concerned with noise, and consider the future research needs.

These proceedings are organized in the same order as the seminar, which consisted of five sessions. The first session on sources of noise includes papers on noise from traffic, industry, recreation, and domestic activities. The second session contains papers dealing with the effects of noise on people. Not only is the loss of hearing discussed but also the psychological effects. The third session includes papers on noise control and abatement in the community. Session four contains several papers describing monitoring studies and experiences. The last session summarizes

major conclusions reached in the seminar and highlights the technical areas requiring increased research effort.

This reviewer was pleased that the authors recognized the need for effective enforcement and noise control programs. The text would be improved and more valuable if several case studies and detailed solutions were described at length. Although the information contained in the text was well assembled, it is not well bound.

The book is easy to read. It is not very technical in nature but will give those with the responsibility of enforcing standards or writing guidelines an awareness of the problems encountered by local authorities. The book underscores the importance of community noise and focuses attention on noise pollution. It is recommended for those with an interest in or charged with the responsibility of community noise pollution control.

V.R. Miller
5331 Pathview Drive
Huber Heights, OH 45424

ADVANCES IN DYNAMIC ANALYSIS AND TESTING

R.W. Mustain, editor
SAE, Warrendale, PA
SP-529, 1982, 61 pages

This book is a report of a one-day symposium held in October, 1982. The editor, who is vice-chairman of the SAE G-5 Aerospace Shock and Vibration Committee, organized the sessions. In-depth reviews of dynamics testing and analysis are presented.

The first of the six papers in the book contains a summary of work on the application of pulse excitation techniques. These techniques utilize such large energy devices as point source explosions, chemical rockets, and metal cutting and are used to test and evaluate the dynamic response of large structures subjected to transient motion loads.

The second paper is an excellent review of modal analysis and testing of large scale structures. The four steps include pretest modeling using finite elements, dynamic testing; identification of resonant frequencies, mode shapes, and modal damping; and post-test model refinement by structural estimation techniques.

The third paper is a brief review of isolator fundamentals. The authors consider a special case of modal analysis of nonlinear pneumatic vibration isolators subjected to different load conditions. A computer model of the frequency response of the isolator is formulated by curve fitting a Laplace polynomial to the empirical transfer function.

The next paper introduces optimum multiple shaker control. The four shaker system, which is in late stages of completion, contains cross-coupling control in a closed loop system with partially coherent control points. The objective of this system is to provide multiple inputs that can produce desired cross spectral density response at each multiple control point. A master computer with a satellite CPU for each shaker controls the inputs.

The fifth paper outlines procedures for modal analysis and testing of nuclear plant equipment applied to energy reactor shutdown. The authors consider both acceptance and qualification analysis applied to testing NRC equipment for seismic and hydrodynamic loading conditions. The analysis/test procedure consists of developing a finite element model and modal test program (math model verification). These are applied to low level transmissibility tests used in developing instrument response spectra employed in acceptance criteria for instruments and accessories.

The last paper compares results from four tests in spacecraft. They are very low level random, one third level sine, and full level sine. The authors propose to show that both sinusoidal and random vibrations can be analyzed when overlap processing is used to obtain the required modal data.

The sessions provide useful information about analysis (finite elements) and testing (modal analysis and qualification testing).

H. Saunders
General Electric Company
Building 41, Room 307
Schenectady, NY 12345

ENERGY AND NOISE

R.K. Miller
Fairmont Press, Atlanta, GA
1981, 134 pages, $45.00

This book is a disjoined compilation of existing literature. A book on this topic could be useful if properly done; unfortunately this one is not well done.

The book contains eleven short chapters of sketchy information. The chapters are: The Correlation between Energy and Noise, Noise Basics, Energy Conservation Basics, Acoustical Enclosures and Heat Recovery, Pneumatic Systems, HVAC Systems, Steam and Air Leaks, Building Construction, Employee Awareness Programs, Energy and Noise Maintenance, and Economic Analysis.

It is of interest that two of the chapters (7 and 8) were not written by the author. There is no index and very little original work from the author.

As a potential text for students or as a handbook for novice noise control engineers, the book would not be suitable. The experienced engineer would be better off using information available from other texts.

V.R. Miller
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SHORT COURSES

NOVEMBER

MACHINERY VIBRATION ENGINEERING

Dates: November 1-4, 1983
Place: Cincinnati, Ohio
Dates: January 24-27, 1984
Place: Houston, Texas
Dates: July 17-20, 1984
Place: Oak Brook, Illinois
Dates: November 27-30, 1984
Place: Washington, D.C.

Objective: Techniques for the solution of machinery vibration problems will be discussed. These techniques are based on the knowledge of the dynamics of machinery; vibration measurement, computation, and analysis; and machinery characteristics. The techniques will be illustrated with case histories involving field and design problems. Familiarity with the methods will be gained by participants in the workshops. The course will include lectures on natural frequency, resonance, and critical speed determination for rotating and reciprocating equipment using test and computational techniques; equipment evaluation techniques including test equipment; vibration analysis of general equipment including bearings and gears using the time and frequency domains; vibratory forces in rotating and reciprocating equipment; torsional vibration measurement, analysis, and computation on systems involving engines, compressors, pumps, and motors; basic rotor dynamics including fluid film bearing characteristics, critical speeds, instabilities, and mass imbalance response; and vibration control including isolation and damping of equipment installation.

Contact: The Vibration Institute, 101 West 55th Street, Clarendon Hills, IL 60514 - (312) 654-2254.

DIGITAL SIGNAL PROCESSING

Dates: November 14-16, 1983
Place: Troy, Michigan

Objective: The course is intended for engineers and technicians currently working in vibration, acoustics and related areas of technology. The lectures and demonstrations will present basic concepts and in-depth presentations on a variety of related subjects, including measurements, Fourier analysis theory, digital signal processing, calibration and excitation techniques. The course is designed to provide attendees with a thorough understanding of fundamental measurement theory as well as practical experience, by combining classroom lectures with laboratory sessions and demonstrations.

Contact: Mary Donaghue, Structural/Kinematics, 351 Executive Drive, Troy, MI 48084 - (313) 497-6670.

LECTURE/TRAINING COURSE ON NAVAL SHOCK

Dates: November 14-18, 1983
Place: Washington, D.C.
Dates: January 9-13, 1984
Place: San Diego, CA

Objective: Combat survivability is a key issue in the design of naval ships. Current DoD policy highlights survivability as an essential requirement in the ship acquisition process. The wars in South East Asia, the Middle East and, recently, in the Falkland Island conflict accentuated the need for combat survivability. Since shock induced by various weapons is a major and highly destructive weapon effect, design for survival under shock is a vital part of the ship survivability process. Hence, under present Navy policy, all mission-essential equipment must qualify to rigorous shock hardening requirements. Naval Systems Commands and Laboratories, shipbuilders and equipment suppliers all play a role in the shock hardening process. If you work for the Navy, you may be involved in the implementation and verification of the Navy shock requirements, or you may be responsible for the purchase of electronic or weapon systems that must be shock qualified. As an employee of a major shipbuilder or a Naval equipment supplier, you may be faced with broad and/or specific aspects of Naval shock design. This lecture/training course has been developed to help engineers,

scientists, Naval architects and others understand and effectively deal with the U.S. Navy's ship shock hardening requirements. If you are faced with ship shock problems, participation in this course should increase your value to your organization and enhance your own career advancement.

Contact: Henry C. Pusey or Maurisa Gohde, NKF Engineering Associates, Inc., 8150 Leesburg Pike, Suite 700, Vienna, VA 22180 - (703) 442-8900.

MACHINERY VIBRATION ANALYSIS

Dates: November 15-18, 1983
Place: Chicago, Illinois
Dates: February 21-24, 1984
Place: San Francisco, California
Dates: May 15-18, 1984
Place: Nashville, Tennessee
Dates: August 14-17, 1984
Place: New Orleans, Louisiana
Dates: November 13-16, 1984
Place: Cincinnato, Ohio

Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow-speed paper rolls.

Contact: The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

DYNAMIC BALANCING

Dates: November 16-17, 1983
Place: Columbus, Ohio

Objective: Balancing experts will contribute a series of lectures on field balancing and balancing machines. Subjects include: field balancing methods; single, two and multi-plane balancing techniques; balancing tolerances and correction methods. The latest in-place balancing techniques will be demonstrated and used in the workshops. Balancing machines equipped with microprocessor instrumentation will also be demonstrated in the workshop sessions. Each student will be involved in hands-on problem-solving using the various balancing techniques.

Contact: R.E. Ellis, IRD Mechanalysis, Inc., 6150 Huntley Road, Columbus, OH 43229 - (614) 885-5376.

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: November 21-25, 1983
Place: Ottawa, Ontario
Dates: November 28 - December 3, 1983
Place: Cincinnati, Ohio
Dates: December 5-9, 1983
Place: Santa Barbara, California
Dates: February 6-10, 1984
Place: Santa Barbara, California
Dates: March 5-9, 1984
Place: Washington, D.C.

Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos Street, Santa Barbara, CA 93105 - (805) 682-7171.

DECEMBER

SCALE MODELING IN ENGINEERING DYNAMICS

Dates: December 5-9, 1983
Place: Washington, D.C.

Objective: The course will begin with a drop test demonstration of damage to model and prototype

cantilever beams made from different materials. These tests help to introduce the concepts of similarity and of physical dimensions which are preliminary to any model analysis. Formal mathematical techniques of modeling will then be presented including the development of scaling laws from both differential equations and the Buckingham Pi Theorem. A number of sessions then follow wherein the instructors present specific analyses relating to a variety of dynamic vibrations and transient response problems. The problems are selected to illustrate the use of models as an analysis tool and to give examples of variations on different modeling techniques. Types of problems presented include impact, blast, fragmentation, and thermal pulses on ground, air and floating structures.

Contact: Wilfred E. Baker, Southwest Research Institute, P.O. Box 28510, San Antonio, TX 78284 - (512) 684-5111, Ext. 2303.

RELIABILITY DESIGN TRAINING COURSE

Dates: December 12-15, 1983

Place: Orlando, Florida

Objective: The course introduces the basic concepts and theory of reliability engineering along with rudimentary mathematical relationships and emphasizes the practical application of reliability tools which can be used by the designer. Major elements contained in the course include: part selection, specification and control (including screening and qualification); part derating and derating guidelines; reliability allocation and prediction; reliability analysis including FMECA's and fault trees; reliability testing including formal demonstration testing; reliability program management; reliability design techniques such as redundancy and environmental protection, design simplification and analysis; maintenance and maintainability considerations; CMOS and electrostatic discharge considerations; and life cycle cost and design-to-cost philosophies.

Contact: Ms. Nan Pfrimmer, Reliability Analysis Center, RADC/RAC, Griffiss AFB, NY 13441 - (315) 330-4151.

APRIL

ROTOR DYNAMICS

Dates: April 30 - May 4, 1984

Place: Syria, Virginia

Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

Call for Papers

MECHANICAL FAILURES PREVENTION GROUP 39th SYMPOSIUM "Failure Mechanisms in High Performance Materials" May 1-3, 1984, Gaithersburg, Maryland

The Mechanical Failures Prevention Group (MFPG), under sponsorship of the National Bureau of Standards, will hold its 39th Symposium at the National Bureau of Standards, Gaithersburg, Maryland, May 1-3, 1984.

The emphasis of this meeting will be the identification and interpretation of degradation and failure modes in high performance materials. High performance materials to be considered include these examples: high technology metals -- metallic glasses, rapidly solidified metals; metal powder products; composites -- metal-matrix composites, fiber composites; and advanced nonmetallic materials -- structural ceramics, polymer concrete.

Higher materials performance requirements in both civilian and defense applications have led the materials community to develop either new classes of materials to meet these service requirements, or new materials processing technologies to enhance the performance of existing materials. High performance materials often have unique properties that make the present understanding of failure mechanisms and the predictive capability of failure models inadequate when applied to these materials. This may result in decreased component reliability or service life because of accelerated degradation of critical properties.

A proceedings of this Symposium will be published by Cambridge University Press and will be distributed to all conference registrants without charge.

Authors should submit the title of their presentation and short abstract (200 - 300 words) by December 1, 1983 to: Dr. J.G. Early, Metallurgy Division, Room A153, Building 223, National Bureau of Standards, Washington, D.C. 20234.

First Announcement

19th MIDWESTERN MECHANICS CONFERENCE Ohio State University September 9-11, 1985

The 19th MMC will be held at Columbus, Ohio from September 9-11, 1985. The conference will be hosted by the Department of Engineering Mechanics, College of Engineering, Ohio State University.

Midwestern Mechanics Conferences have been held once every two years since 1950. The second one was held on the OSU campus in 1951. The technical program will consist of keynote and invited lecturers as well as contributed papers from all areas of mechanics. There is no restriction on geographic location of authors.

For convenience in planning ahead, it is of interest to note that the ASME Conference on Mechanical Vibration and Noise will be held in Cincinnati, Ohio, September 11-13, 1985. Cincinnati is approximately 100 miles to the southwest of Columbus.

For further information contact: Professors S.H. Advani or A.W. Leissa, Department of Engineering Mechanics, Ohio State University, Columbus, OH 43210 - (614) 422-2731/2680.

ACTIVITIES IN ACOUSTICS, VIBRATIONS AND NOISE CONTROL

The Department of Mechanical Engineering at Stevens Institute of Technology conducts ongoing research supported by industry and other agencies at its Noise and Vibration Control Laboratory. In addition, courses in acoustics, vibrations and noise control are offered at both the undergraduate and graduate levels. Students also have an opportunity to participate in design projects involving a variety of engineering problems in the area of industrial and environmental noise control.

The Noise and Vibration Control Laboratory is a part of the machine systems program which also includes computer-aided design, automatic controls and experimental methods. The Noise and Vibration Control Laboratory was dedicated in May of 1981. Members of the Stevens' Class of 1939 provided support for much of the equipment in the laboratory. The equipment includes frequency analyzers, instrumentation tape recorders, precision sound level meters and vibration related instruments. Future plans include addition of an anechoic chamber to provide a sound-proof test environment.

The Institute recently was awarded a contract from IBM to conduct studies on acoustical source idealization of vibrating structures. Under this contract, Dr. M.G. Prasad and his research associates are conducting analytical and experimental studies to predict acoustical fields of various model structures.

A mini-graduate program in vibrations and noise control is available for working professionals wishing to specialize in this area. This program consists of four graduate level courses. Typical courses are Engineering Acoustics, Mechanical Vibrations, Noise Control, Analytic Dynamics, Vibrations and Noise Control, and Acoustic and Noise Measurements.

For further information contact: Dr. M.G. Prasad, Department of Mechanical Engineering, Stevens Institute of Technology, Castle Point Station, Hoboken, NJ 07030 - (201) 420-5571.

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of publications abstracted are not available from SVIC or the Vibration Institute, except those generated by either organization. Government Reports (AD-, PB-, or N-numbers) can be obtained from NTIS, Springfield, Virginia 22151; Dissertations (DA-) from University Microfilms, 313 N. Fir St., Ann Arbor, Michigan 48106; U.S. Patents from the Commissioner of Patents, Washington, DC 20231; Chinese publications (CSTA-) in Chinese or English translation from International Information Service Ltd., P.O. Box 24683, ABD Post Office, Hong Kong. In all cases the appropriate code number should be cited. All other inquiries should be directed to libraries. The address of only the first author is listed in the citation. The list of periodicals scanned is published in issues 1, 6, and 12.

ABSTRACT CONTENTS

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 1956, 2129, 2130)

83-1930

Vibration of Rotating Disks

G.M. Diehl

Compressed Air, 88 (6), pp 22-25 (June 1983) 3 figs

Key Words: Disks, Resonant frequencies

The article explains why a small steady force at a disk's critical speed can produce a dangerous vibration. It also compares the vibration characteristics of rotating disks to those of rotating shafts.

83-1931

Structural Models and Undamped Torsional Natural Frequencies of a Superconducting Turbogenerator Rotor

J.R. Bumby and J.M. Wilson

Dept. of Engrg., Univ. of Durham, Durham DH1 3LE, UK, J. Sound Vib., 87 (4), pp 589-602 (Apr 22, 1983) 7 figs, 6 tables, 11 refs

Key Words: Rotors, Turbogenerators, Natural frequencies, Torsional vibration

Superconducting turbogenerators with a double rotor structure have a torsional natural frequency within the generator, the outer rotor moving in opposition to the inner rotor. For large machines this natural frequency may approach 100 Hz. In this paper a finite element model and simple lumped mass and spring models of the rotor, for the calculation of the undamped torsional natural frequencies, are described and compared. A method by which equivalent spring stiffnesses for both the inner and outer rotors can be derived is described, allowing one to use a rotor model with one lumped mass and equivalent spring stiffness for each of the inner and outer rotors. Such a rotor model can be readily used for studying electromagnetic interaction effects and assessing fault torques in the outer rotor and inner rotor torque tubes.

83-1932

Electrical Damping and Its Effect on Accumulative Fatigue Life Expenditure of Turbine-Generator Shafts Following Worst-Case Supply System Disturbances

T.J. Hammons

Dept. of Electrical Engrg., Glasgow Univ., Glasgow G12 8QQ, UK, IEEE Trans., Power Apparatus Syst., PAS-102 (6), pp 1552-1569 (June 1983) 17 figs, 5 tables, 6 refs

Key Words: Shafts, Fatigue life, Torsional vibration, Damping effects

The effect of electrical phenomena on damping torsional vibrations of turbine-generator shafts resulting from severe disturbances on the system supply is examined. The effect of system impedance and power factor on time constants for decay of predominant shaft torsional vibrations and on fatigue life expenditure of the shaft following worst-case events is investigated. The impact of pole slipping resulting from delayed fault clearance on peak shaft torque and on accumulative fatigue life expenditure of the shaft is also examined.

83-1933

Sound Propagation through Radial Passages in Turbomachines

D.K. Holger

Iowa State Univ., Dept. of Engrg. Science and Mechanics, 205A ERI Bldg., Ames, IA 50011, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 207-216, 2 figs, 6 refs

Key Words: Turbomachinery, Sound propagation

A significant source of acoustic energy in centrifugal turbomachinery is the compressor. In order to design a quiet compressor, it is necessary to understand how acoustic energy propagates through the components of a compressor. The impeller is a major source of acoustic energy in compressors, and thus the radial diffuser, immediately downstream from the impeller, is a component in which it would be desirable to attenuate propagating sound. This paper reports some results of an investigation of acoustic propagation through a vaneless radial diffuser with absorptive walls. In particular, the effects on propagation of radial outflow through the diffuser are examined.

83-1934

Aeroelastic Stability and Dynamic Response Analysis of the LDB-125 Vertical Axis Wind Turbine

A. Vollan

Aeronautical Res. Inst. of Sweden, Stockholm, Sweden, Rept. No. FFA-TN-1982-19, 57 pp (Aug 1982)

N83-18028

Key Words: Wind turbines, Aeroelasticity

The stability and dynamic response behavior of the proposed vertical axis wind turbine LDB-125 is investigated. The LDB rotor imposes many new and unconventional features such as double L blades, inclined tower, rotating base, extensive use of guy wires. A dynamic response and stability analysis is performed using a complex calculation model to minimize the risk of neglecting significant physical effects. It is shown, that the LDB-125 rotor has no instabilities or dangerous resonance regions in the normal operating range of rotational velocity.

83-1935

Noise Control for Roof-Mounted Air Conditioning Condensing Units

A.H. Marsh

DyTec Engineering, Inc., 5092 Tasman Dr., Huntington Beach, CA 92649, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Mar 21-23, 1983, pp 269-276, 3 figs, 2 tables, 3 refs

Key Words: Air conditioning equipment, Multistory buildings, Noise reduction

An existing four-story eight-apartment building was to be renovated by removal of the top floor and construction of a deluxe penthouse. The renovated building was to have nine condensing units on the roof. Before a building permit would be issued, it was necessary to show, analytically, that noise from the nine roof-mounted condensing units would not exceed an established limit for property-line noise.

83-1936

Sound Power Levels of a 36" Diameter Plug Fan

J.G. Lilly and R.M. Towne

Towne, Richards and Chaudiere, Inc., 105 N.E. 56th St., Seattle, WA 98105, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 285-292, 8 figs, 3 tables, 2 refs

Key Words: Fans, Air conditioning equipment, Noise reduction

This paper describes a fan system which is qualified to handle the task of supplying air in a floor by floor system with a minimum amount of noise generation at a competitive price. The paper is based on a six-month series of acoustical tests which were designed to determine the sound power levels of a plug fan in a variety of unit configurations and operating points.

83-1937

A Review of the Physics of Axial Fan Acoustics and Aerodynamics with a View Toward Noise Control

L.M. Gray

Airflow Res. and Mfg. Corp., 110 Coolidge Hill Rd., Watertown, MA 02178, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Mar 21-23, 1983, pp 187-196, 10 figs, 12 refs

Key Words: Fans, Noise generation, Noise reduction

The noise produced by axial flow fans has been the concern of many investigations, by manufacturers, users, and researchers. A large number of these investigations are published in one form or another, and provide the basis of ongoing work in this field. The purpose of this paper is to review the physical mechanisms which cause noise in axial flow fans. An understanding of these mechanisms should allow one to critically review the results of fan noise investigations, or to guide a fan system design process, to yield the lowest fan noise. In addition, the basic fan laws are reviewed.

83-1938

Tonal Fan Casing Noise Case History

A.L. Mielnicka-Pate, T.R. Norris, and M.M. Gmerek

Dept. of Engrg. Science and Mechanics, Iowa State Univ., Ames, IA 50011, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 293-296, 4 figs, 5 refs

Key Words: Fans, Casings, Noise generation

At several industrial plants, tonal fan casing radiated noise has caused environmental problems. All the fans studied

were centrifugal, radial bladed, and consumed 25 to 60 horsepower. There were three different fan models and a total of 16 fans. Casing noise was significant for all of these fan models. Available data on the fan casing noise power show that the ratio of tonal casing noise power varied in the range of 0-5 dB compared with the tonal fan power levels.

83-1939

Engine Cooling System Quieting

M.A. Staiano

Staiano Engineering, Inc., 1923 Stanely Ave., Rockville, MD 20851, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 239-246, 2 figs, 1 table, 6 refs

Key Words: Engines, Fans, Noise reduction

This paper summarizes part of an effort, sponsored by the U.S. EPA, exploring means of making engine cooling fan installations inherently quieter.

83-1940

Practical Aspects of Centrifugal-Fan-Noise Control

F.H. Brittain and T.R. Norris

Bechtel Group, Inc., Res. and Engrg., 50 Beale St., San Francisco, CA 94105, NOISE-CON 83. Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 277-284

Key Words: Fans, Noise reduction, Design techniques

Casing and duct noise from centrifugal fans cannot be controlled effectively by designing a noise-control device solely to meet noise-reduction requirements. Many additional engineering details affect operation of the noise-control device and fan, and must be considered in the design. These considerations include the noise-control device's susceptibility to corrosion and fouling, the ease of installing the device, and its life-cycle cost.

83-1941

Discrete Frequency Noise and Its Reduction in Small Axial-Flow Fans

J.M. Fitzgerald and G.C. Lauchle

The Pennsylvania State Univ., P.O. Box 30, State College, PA 16801, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 223-230, 8 figs, 5 refs

Key Words: Fans, Noise generation, Noise reduction

The basic objective of the work reported on here is to demonstrate that the discrete frequency noise generated by representative axial-flow cooling fans commonly used in electronic equipment may be reduced. It is implied that the reduction of this noise be achieved without degradation of the aerodynamic performance of these fans.

83-1942

The Little Black Fan as a Noise Source

A.L. Boggess, Jr.

EG&G Rotron, Hasbrouck Lane, Woodstock, NY 12498, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 217-222, 5 refs

Key Words: Fans, Noise generation

This paper discusses fan noise and takes some of the mystery and misunderstanding out of choosing a quiet fan. The target of the discussion is axial fans producing less than 300 cfm and, more particularly, less than 100 cfm, which are used in electronic equipment and computers in the office environment.

RECIPROCATING MACHINES

83-1943

The Mechanism of Piston Slap Noise

J.W. Slack

81 Prentiss St., Cambridge, MA 02140, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 105-112, 7 figs, 5 refs

Key Words: Diesel engines, Noise generation

Piston slap is an important source of noise in diesel engines and has been the subject of substantial research for over

twenty-five years. Piston slap is the impact of the piston against the cylinder wall. The purpose of this paper is to develop a model which predicts the spectrum of the force exerted by the piston on the cylinder wall. Dynamic models were developed for both the piston and cylinder wall, and these models were used to predict piston-cylinder wall interaction. An estimate of the kinetic energy of the impact is used to determine the overall level of excitation. The results are presented as cylinder wall vibration velocity spectra; with the model prediction compared to piston slap excited vibration measured on a motored 2.37 liter four stroke naturally aspirated diesel engine.

83-1944

Reduction of Noise Emitted by Medium-Speed Diesel Engines by Partial Encasing

G. Donath and M. Fackler

Maschinenfabrik Augsburg-Nuernberg A.G., Augsburg, Fed. Rep. Germany, Rept. No. BMFT, FB-HA-82-018, ISSN-0171-7618, 56 pp (Sept 1982)

N83-17885

(In German)

Key Words: Diesel engines, Noise reduction, Cladding effect

Reduction of the overall noise level of medium speed diesel engines by covering a large part of the surface with engine borne cladding was investigated. The experimental encapsulation reduced the noise level by 11.5 dB(A), with almost complete cladding of the surface. It is shown that the restriction of the cladding to the louder upper parts was not very beneficial.

83-1945

Vibration-Free Internal Combustion Engine for General Aviation

P. Limbach, Jr.

Limbach-Motorenbau, Koenigswinter, Fed. Rep. Germany, Rept. No. BMFT-FB-W-82-016, ISSN-0170-1339, 58 pp (Aug 1982)

N83-16347

(In German)

Key Words: Internal combustion engines, Vibration measurement

A working engine model was designed and built in order to demonstrate that engines based on the Huf principle are possible. Function, certain design features, and results of vibration measurements on the first Huf-engine built, the HL 2000, are outlined. During test runs reduction of the vibration level of up to 70% was observed, as compared to conventional piston engines.

METAL WORKING AND FORMING

(Also see No. 2067)

83-1946

Control of Noise Exposure in Foundry and Metal Casting Industries

R.C. Potter, C.R. Jokel, and J.F. Potter

Bolt Beranek and Newman, Inc., Cambridge, MA, S/V, Sound Vib., 17 (5), pp 14-19 (May 1983) 8 figs, 3 tables, 4 refs

Key Words: Industrial facilities, Noise generation, Metal working, Noise reduction

Noise exposures in the foundry and metal casting industry are reviewed in terms of their extent and causes. Suggestions for engineering controls of specific excessive noise sources are also presented.

83-1947

An Evaluation of a Linear Model for the Description of a Structure-borne Noise in Machine Tools (Betrachtung eines linearen Modells zur Beschreibung der Korperschallubertragungsvorgange in Werkzeugmaschinen)

J. Schwartz

Industrie Anzeiger, 11 (37), pp 29-30 (May 11, 1983)

Key Words: Machine tools, Structure-borne noise, Noise reduction

The dynamic behavior of a machine tool affects the quality of the finished work piece, machine capacity, fatigue life, and accuracy of the machine. In addition to machinery noise sources such as hydraulics and engines, the structure-borne noise transmission paths between the noise source and the point under investigation are also significant. A linear expression is presented for the determination of the effect of every individual noise source on any measurable point in the machine, so that appropriate means for noise reduction can be taken.

83-1948

Development of a Quiet Jumbo Drill: Evaluation of Design Concepts

P.K. Dutta, P.W. Runstadler, Jr., and R.C. Bartholomae

Creare Products, Inc., Etna Rd., Lebanon, NH 03766, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 169-176, 4 figs, 4 refs

Key Words: Drills, Pneumatic tools, Mining equipment, Noise reduction, Design techniques

This paper summarizes the results of a study to design, develop, and demonstrate pneumatic percussive class jumbo drill noise-reducing technology. The noise-reducing features that evolved from this study are applicable to future designs of jumbo mounted drills that can be cost-effectively manufactured and, when used in the mining environment, have the potential to produce overall noise levels at the operator's ear of 90 dBA or less, without a reduction of currently attainable drilling rates.

83-1949

Noise Emission Event Analysis – An Overview

R.R. James and W.W. Ament

Total Environmental Systems, Inc., 414 N. Larch, Lansing, MI 48912, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 433-442, 4 tables

Key Words: Presses, Noise reduction, Human response, Computer programs

The methodology used in the User's Guide for Noise Emission Event Analysis and Control, developed for noise control of power presses, is discussed. It combines a sequence of analytical techniques that separate the complex series of sounds produced during a power press cycle into individual process oriented components. It then provides a computer program for evaluating the contribution of each noise emitted to the press operator, and simulation of noise reduction techniques.

83-1950

Identification of Components of Power Press Noise

R.E. Balck

Balck Engineers, 957 Maxwell Ave., S.E., Grand Rapids, MI 49506, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 443-452, 4 figs

Key Words: Presses, Noise source identification

The total noise reaching the operator of a power press is usually the sum of many individual noise sources. These individual sources combine acoustically in a complex manner. When noise control efforts treat the press as a single noise source, as when a total enclosure is prescribed, individual noise components need not be dealt with. However, when efforts are made to reduce the operator's noise exposure using primarily engineering noise control techniques, knowledge of the identity and magnitude of individual noise sources is important. Press analysis can yield information on ten, twenty, or more individual noise sources.

83-1951

Reduction of Impact Noise in Mechanical Presses

B. Huang and E.I. Rivin

Ford Motor Co., Mfg. Processes Lab., 24500 Glendale, Redford, MI 48239, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusettts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 425-432, 9 figs, 7 refs

Key Words: Presses, Impact noise, Noise reduction

Major noise generating mechanisms in mechanical presses have been identified as blanking or shearing, impacts between machine members, compressed air discharges, and ejecting parts onto chutes or containers. This paper discusses some aspects of noise generated by impacts in a press structure.

83-1952

A Novel Damper for Reducing Percussive Tool Noise

A.J. DiBianca, J.A. Lacey, W.C. Kennedy, and H.A. Scarton

Lab. for Noise Control Res., Dept. of Mech. Engrg., Rensselaer Polytechnic Inst., Troy, NY 12181, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts

Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 99-104, 2 figs, 3 refs

Key Words: Tools, Noise reduction, Material damping

High-frequency sound radiated by chisels or peens constitutes a major component of the noise signature of percussive tools. This high frequency sound component arises because the chisel or peen rings in response to the impacts received from the tool hammer and the workpiece. A number of different methods for reducing the severity of the ringing have been tried, but none of them has proven suitable for implementation on the shop floor. Because of the problems encountered when employing these different approaches, fresh insights are necessary if satisfactory methods for reducing ringing are to be developed and implemented. The purpose of this paper is to summarize work performed with this end in mind and to describe the results achieved when insights obtained in the course of this work were incorporated into a damper for a peen.

STRUCTURAL SYSTEMS

BRIDGES

83-1953

Vertical and Lateral Dynamic Response of Railway Bridges Due to Nonlinear Vehicles and Track Irregularities

M.H. Bhatti

Ph.D. Thesis, Illinois Inst. of Tech., 159 pp (1982)

DA8307040

Key Words: Bridges, Railroad bridges, Interaction: rail-vehicle

A method was developed to study the dynamic response of a railway bridge caused by the vehicle-track-bridge interactions in both vertical and lateral directions. Analytical models for the bridge and nonlinear freight car were developed. Responses in selected bridge members, due to random inputs from track irregularities, were evaluated in terms of forces and impact. Fatigue life of a critical hanger in the bridge was determined.

BUILDINGS

83-1954

Influence of Nonstructural Cladding on Dynamic Properties and Performance of Highrise Buildings

H. Palsson

Ph.D. Thesis, Georgia Inst. of Tech., 462 pp (1982)

DA8310656

Key Words: Buildings, Multistory buildings, Cladding effect

Precast concrete panels provide an attractive facade, lend an aesthetic appeal and are becoming increasingly popular for steel frame buildings. Results of recent research have shown that cladding-structure interaction can change the dynamic properties of overall structural systems significantly. As a case study the influence of precast concrete panels on the lateral and torsional stiffness of a 25-story office building was investigated.

83-1955

Cumulative Damage in Components of Steel Structures under Cyclic Inelastic Loading

M. Zohrei

Ph.D. Thesis, Stanford Univ., 257 pp (1983)

DA8307248

Key Words: Buildings, Steel, Cyclic loading, Seismic response, Fatigue life

The objective of the work presented in this dissertation is to quantify cumulative damage in structural components subjected to cyclic inelastic loading histories. The cumulative damage models developed in this research can serve as a basis for assessing the safety against failure of steel structures in severe earthquakes. Two series of experiments were performed in order to evaluate damage accumulation and resistance deterioration due to local buckling in beam flanges and crack propagation at weldments.

TOWERS

83-1956

Arlis 1.0: Linear Investigation of Aeroelastic Systems in Rotation (Arlis 1.0: Aeroelastiche Analyse Rotierender Linear Systems)

J.H. Argyris and B. Kirchgaessner

Inst. fuer Statik und Dynamik der Luft- und Raumfahrtkonstruktionen, Stuttgart Univ., Fed. Rep. Germany, Rept. No. ISD-293, ISSN-0170-6071, 162 pp (1982)
N83-17905
(In German)

Key Words: Wind mills, Aeroelasticity, Towers, Rotors

A program system for linear investigation of the dynamic behavior of wind energy converters is described. Tower and rotor are coupled modally to obtain linearized equations of motion of the entire system. The investigation of stability is performed according to Floquet's theory. The theory, a program and some examples which were investigated are described.

ROADS AND TRACKS

83-1957
The Poro-Elastic Road Surface – A New Tool for Controlling Traffic Noise
N.-A. Nilsson
IFM Akustikbyran AB, Warfvinges vag 26, S-112 51 Stockholm, Sweden, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 375-378, 4 figs, 4 refs

Key Words: Traffic noise, Noise reduction, Roads (pavements)

A cost-effective method for controlling traffic noise by means of poro-elastic road surface is described. The poro-elastic surface is made of granulated rubber of carefully controlled grain size bonded with a binder; e.g., polyurethane, providing acoustically active pores and cavities.

POWER PLANTS
(See No. 2103)

OFF-SHORE STRUCTURES

83-1958
The Effect of Wave-Current Interactions on the Hydrodynamic Loading of Large Offshore Structures
R.K. Watanabe
Ph.D. Thesis, Texas A&M Univ., 160 pp (1982)
DA8306830

Key Words: Off-shore structures, Wave forces, Finite element technique, Hydrodynamic excitation

The influence of wave-current interactions on the fluid loading of large offshore structures is investigated by extending the conventional diffraction theory approach to include the changes in the incident and scattered wave fields caused by the presence of a steady current. Modifications in the wave height are based upon the principle of conservation of wave action. The waves are assumed to be linear so that the effect of the current on the short-term force spectrum can be determined from the transfer function and modified Pierson-Moskowitz spectrum.

VEHICLE SYSTEMS

GROUND VEHICLES
(Also see Nos. 1957, 1984, 1987, 1988, 1989, 1990, 2004)

83-1959
Analysis of the Generating Mechanism of Engine Noise Caused by the Natural Vibration of the Cylinder Block
M. Ishihama
Room 9-426, Center for Advanced Engrg. Study, Massachusetts Inst. Tech., Cambridge, MA 02139, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 161-168, 10 figs, 2 refs

Key Words: Automobile noise, Engine noise, Noise generation

Engine noise, the dominant factor in noise emitted from automobiles, consists of both combustion noise and mechanical noise and is strongly influenced by natural vibration of the engine structure in the frequency range from 500 to 2k Hz. Results of an experimental study using a four-cylinder gasoline engine to clarify the exciting force and response with respect to lateral bending mode of the engine structure are presented.

83-1960

Diesel Locomotive Cab Noise: A Methodology for Analysis

N.A. Shelley

British Railways Board, Res. and Dev. Div., Railway Technical Ctr., London Road, Derby DE2 8UP, UK, J. Sound Vib., 87 (2), pp 241-245 (Mar 22, 1983) 3 figs

Key Words: Locomotives, Noise generation

Noise levels in diesel locomotive cabs can exceed certain relevant criteria. This report details a methodology that can be used to quickly examine a problem locomotive cab and guide toward the correct palliative treatment.

83-1961

Some Developments in Community Response Research Since the Second International Workshop on Railway and Tracked Transit System Noise in 1978

R.G. De Jong

TNO Res. Inst. for Environmental Hygiene, P.O. Box 214, 2600 AE Delft, The Netherlands, J. Sound Vib., 87 (2), pp 297-309 (Mar 22, 1983) 6 figs, 2 tables, 38 refs

Key Words: Railroad trains, Noise generation

Developments regarding human responses to railway noise are discussed.

83-1962

Railway Noise Prediction – Data Base Requirements

B. Hemsworth

British Railways Board, Res. and Dev. Div., Railway Technical Ctr., London Rd., Derby DE2 8UP, UK, J. Sound Vib., 87 (2), pp 275-283 (Mar 22, 1983) 7 figs, 14 refs

Key Words: Railroad trains, Noise prediction

An assessment is made of the data available on the propagation of noise from a railway line by describing a building block approach to the prediction of wayside noise levels. It is suggested that in certain areas; e.g., track in cutting and the effects of housing development, the sparsity of statically validated data often means that accurate predictions can only be made when specific measurements are made to cover the situation under consideration.

83-1963

Diagnostic Methods in the Control of Railway Noise and Vibration

J. Melke and S. Kraemer

TÜV Rheinland e.V., Cologne, Fed. Rep. Germany, J. Sound Vib., 87 (2), pp 377-386 (Mar 22, 1983) 10 figs, 5 refs

Key Words: Railroad trains, Vibration prediction, Diagnostic techniques

A method for investigating urban railway vibrations by using diagnostic measurement techniques is discussed and some preliminary results are shown. It is suggested that diagnostic methods could form a useful complement to empirical and analytical vibration prediction models in this field.

83-1964

Propagation of Ground Vibrations Near Railway Tracks

G. Volberg

Garcia-BBM, S.A., Atazar 5, Colmenar Viejo, Madrid, Spain, J. Sound Vib., 87 (2), pp 371-376 (Mar 22, 1983) 5 figs, 2 tables

Key Words: Railroad trains, Ground vibration, Vibration measurement, Vibration prediction

Measurements of vibration propagation were carried out at three different sites with different ground properties. Accelerometers were placed at distances up to 64 m from the center line of railroad tracks. The signals were analyzed in one-third octave bands from 6·3 to 160 Hz. The results are rather independent of the sites investigated. Local differences in vibration level observed at one site are similar to level differences from site to site. For the prediction of train induced vibrations in the vicinity of planned railroad tracks, a simple power law is proposed.

83-1965

Development of an Impact Method to Determine the Vibration Transfer Characteristics of Railway Installations

E.C. Bovey

London Transport Res. Lab., 566 Chiswick High Rd., London W4 5RR, UK, J. Sound Vib., 87 (2), pp 357-370 (Mar 22, 1983) 8 figs, 6 refs

Key Words: Railroad trains, Vibration tests

The development of a method of vibration testing with impact excitation is described. This technique has many

advantages for the investigation of railway installations and has been shown to be a reliable, controlled method for providing quantitative data. A brief outline of the theoretical basis of the method is given and also a description of two site tests where the method was developed and used to measure different aspects of vibration transmission.

83-1966

Ground Vibrations from Heavy Freight Trains

T.M.Dawn
British Railways Board, Res. and Dev. Div., Railway Technical Ctr., London Rd., Derby DE2 8UP, UK, J. Sound Vib., 87 (2), pp 351-356 (Mar 22, 1983) 8 figs, 1 table, 2 refs

Key Words: Railroad trains, Ground vibration

Ground vibration from heavy freight trains on good quality welded track are found to have only a weak dependence on train speed above 30 km/h. At the site on which these tests were carried out a critical speed was found at which the vibration reached a peak. The frequencies of vibration produced appear to be functions of track and vehicle dimensions and the critical speed occurs at the coincidence of sleeper passage frequency and the total vehicle on track resonance frequency.

83-1967

Control of Ground-Borne Noise and Vibration

G.P. Wilson, H.J. Saurenman, and J.T. Nelson
Wilson, Ihrig & Associates, Inc., 5776 Broadway, Oakland, CA 95618, J. Sound Vib., 87 (2), pp 339-350 (Mar 22, 1983) 11 figs, 1 table, 8 refs

Key Words: Railroad trains, Noise reduction, Vibration control, Ground vibration

Ground-borne noise and vibration created by train operations is one of the major environmental problems faced by rail transit systems. In this paper the focus is on two methods of controlling the vibration radiated by the transit structure. First is the use of floating slab trackbeds, a method that has proven to be very effective at reducing vibration at frequencies above the resonance frequency of the floating slab system. Second is to modify the design of transit car bogies such that the wheel/rail forces are reduced.

83-1968

Noise Control for Rapid Transit Cars on Elevated Structures

C.E. Hanson
Harris Miller, Miller & Hanson Inc., 183 Bedford St., Lexington, MA 02173, J. Sound Vib., 87 (2), pp 285-294 (Mar 22, 1983) 7 figs, 3 refs

Key Words: Rapid transit railways, Elevated railroads, Railroad trains, Noise reduction

Noise control treatments for the propulsion motor noise of rapid transit cars on concrete elevated structures and the noise reduction from barrier walls were investigated by using acoustical scale models and supplemented by field measurements of noise from trains. The results show that vehicle skirts and undercar sound absorption can provide substantial cost-effective reductions in propulsion noise at the wayside of transit systems with concrete elevated guideways.

83-1969

Railway Elevated Structure Noise -- A Review

L.E. Wittig
Bolt Beranek and Newman, Inc., 10 Moulton St., Cambridge, MA 02238, J. Sound Vib., 87 (2), pp 249-271 (Mar 22, 1983) 12 figs, 2 tables, 24 refs

Key Words: Elevated railroads, Railroad trains, Rapid transit railways, Noise generation, Interaction: rail-wheel, Reviews

This paper presents a review of recent work concerned with understanding and controlling the noise from railroad and rapid transit elevated structures. The basis of this paper is a study sponsored by the U.S. Department of Transportation, where the emphasis was on locating and analyzing structures in the U.S. responsible for the greatest environmental noise impact.

83-1970

The Noise Behavior of the Wheel/Rail System -- Some Supplementary Results

J. Feldmann
Institut f. Technische Akustik, Technische Universität Berlin, W. Germany, J. Sound Vib., 87 (2), pp 179-187 (Mar 22, 1983) 11 figs, 13 refs

Key Words: Interaction: rail-wheel, Noise generation

Acoustical measurements were carried out on railroad coaches, on standard tracks and in the free field during test runs.

In particular the influences of noise parameters like train speed, track condition, wheel type or locomotive propulsion were examined.

83-1971

Sources and Mechanisms of Wheel/Rail Noise: State-of-the-Art and Recent Research.

T. ten Wolde and C.J.M. Van Ruiten
Inst. of Appl. Physics TNO, P.O. Box 155, 2600 AD Delft, The Netherlands, J. Sound Vib., 87 (2), pp 147-160 (Mar 22, 1983) 13 figs, 18 refs

Key Words: Interaction: rail-wheel, Noise generation

A review is presented of wheel/rail research studies published since 1978. Additionally a study is presented which is focused on the magnitudes and relative importance of vertical and horizontal forces in the wheel/rail contact zone.

83-1972

Consideration of Some Noise Sources Due to Railway Operation

C.G. Stanworth
British Railways Board, Res. and Dev. Div., Railway Technical Ctr., London Rd., Derby DE2 8UP, UK, J. Sound Vib., 87 (2), pp 233-239 (Mar 22, 1983) 4 figs, 4 refs

Key Words: Interaction: rail-wheel, Noise generation

A number of railway operation noise sources other than those leading to the far field (largely wheel/rail), train pass-by noise, are identified and briefly discussed. Sources considered include the following: close proximity wheel/rail noise; locomotive noise; freight vehicle noise; warning signal noise; near field bridge noise; marshalling yard noise; flange squeal on tight curves; maintenance machine noise; and track machinery warning horn noise.

83-1973

Side Impacts: An Analysis of Light Trucks, Intrusion, and Injury in FARS (Fatal Accident Reporting System) and NCSS (National Crash Severity Study) Data

R.E. Scott
Transportation Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UMTRI-82-43, 144 pp (Nov 1982)
PB83-166124

Key Words: Collision research (automotive), Trucks, Automobiles

This report complements an earlier report which was devoted to the subject of side impacts of passenger cars. In this report, side impacts of light trucks are studied with respect to where, how, and why they occur using the data of the Fatal Accident Reporting System (FARS), and the National Crash Severity Study (NCSS). Data from the second phase of the NCSS program is also used to study side-impact injury and their relation to intrusion in both passenger cars and light trucks.

SHIPS

(Also see Nos. 2022, 2127)

83-1974

Coal-Fired Propulsion System Dynamics. Volume 1. Executive Summary

T.L. Greenlee and J.L. Pearsons
Quincy Ship Building Div., General Dynamics Corp., Quincy, MA, Rept. No. MA-RD-920-82063-A, 35 pp (Dec 1982)
PB83-163170

Key Words: Ships, Propulsion systems

This volume summarizes the objectives, scope, and conclusions of an effort that was undertaken to develop and analyze a dynamic model/simulation of a coal-fired ship with steam turbine propulsion system. The effort was sponsored for the purpose of investigating the responsiveness of coal-fired ships in maneuvering and in restricted-water operation. The volume concludes with a set of specification results that indicate the component/control system design trends that should be followed to obtain a rapidly responding coal-fired propulsion system.

83-1975

Coal-Fired Propulsion System Dynamics. Volume III. Dynamic Analysis of the CV-3600

T.L. Greenlee and J.L. Pearsons
Quincy Ship Building Div., General Dynamics Corp.,

Quincy, MA, Rept. No. MA-RD-920-82063, 803 pp (Dec 1982)
PB83-163196

Key Words: Ships, Propulsion systems

This volume summarizes the results of a thorough analysis of the CV-3600 dynamic model that was discussed in Volume II. The purpose of this effort was to determine general engineering details and specifications for coal-fired propulsion systems based on a detailed analysis of a specific propulsion system design. The basis for these specifications included the sensitivity of ship propulsion system response to component parameter and control variations such as grate travel speed and controls, spreader and distributor feed and controls, fan speed and damper controls, steam dump (sizing, control valve characteristics and controls), feedwater pump controls (drum level controls), throttle control, and desuperheater steam attemperation controls.

83-1976

A Hydroelastic Approach to Ship Vibration Problems

P. Kaleff
Dept. of Ocean Engrg., Federal Univ. of Rio de Janeiro, Rio de Janeiro, Brazil, J. Ship Res., 27 (2), pp 103-113 (June 1983) 10 figs, 3 tables, 13 refs

Key Words: Ships, Submerged structures, Interaction: structure-fluid, Cantilever plates, Hamiltonian principle, Natural frequencies, Mode shapes

A procedure is presented to determine the vibration frequencies and mode shapes of submerged structures. Hamilton's principle is used to formulate the problem, and general sequences of trial functions are introduced to permit the direct extremization of the corresponding energy functional. The structure is modeled with finite elements. The accuracy of the hydroelastic procedure is accessed on two examples as compared to experimental data: a cantilever plate and a freely floating ship.

AIRCRAFT

(Also see Nos. 2126, 2128)

83-1977

Studies of Discrete-Tone Rotor-Stator Interaction Noise

G.F. Homicz and G.R. Ludwig
Calspan Advanced Technology Ctr., P.O. Box 400, Buffalo, NY 14225, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 197-206, 5 figs, 14 refs

Key Words: Interaction: rotor-stator, Noise prediction, Aircraft noise

This paper presents the results of comparisons between theory and experiment for the discrete-tone noise generated by rotor-stator interactions. In a previous study, an approximate theoretical model was developed to predict this interaction noise and the predictions were compared to the results of experimental acoustic data obtained in an annular cascade facility upstream of a rotor-stator pair.

83-1978

Impact of the Use of Advanced Composite Material on Panel-Radiated Noise

B.N. Nagarkar
Boeing Commercial Airplane Co., P.O. Box 3707, Seattle, WA 98124, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 153-160, 5 figs, 3 tables, 2 refs

Key Words: Aircraft, Composite materials, Panels, Structure-borne noise

This paper discusses the impact of the use of advanced composite materials in the aircraft industry which has created new challenges for noise control engineers. The advanced composites are stiffer and lighter in weight. These physical properties result in reduced transmission loss and an upward shift in the resonant frequencies.

83-1979

Aircraft Turbofan Noise

J.F. Groeneweg and E.J. Rice
NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TM-83317, 17 pp (1983) (Presented at the 28th Annual Intl. Gas Turbine Conf., Phoenix, AZ, Mar 27-31, 1983)
N83-18405

Key Words: Aircraft noise, Turbofan engines, Noise reduction

Turbofan noise generation and suppression in aircraft engines are reviewed. The chain of physical processes which connect

unsteady flow interactions with fan blades to far field noise is addressed. Mechanism identification and description, duct propagation, radiation and acoustic suppression are discussed. The experimental technique of fan inflow static tests are also discussed.

83-1980
Resonance Tests on the Tail of a CT4 Aircraft
A. Goldman
Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/STRUC-TM-345, 27 pp (Sept 1982)
AD-A124 566

Key Words: Aircraft, Resonance tests

A resonance test has been carried out on the tail section of a CT4 aircraft. Natural modes and frequencies of the tailplane were measured and these results are presented.

83-1981
Prediction of Aerodynamic Loads on Rotorcraft
AGARD, Neuilly-sur-Seine, France, Report No. AGARD-CP-334, 309 pp (Sept 1982) (Presented at Fluid Dyn. Panel Specialists Mtg., London, May 17-18, 1982)
AD-A124 260

Key Words: Helicopters, Aerodynamic Loads

A wide range of aerodynamic phenomena contribute to the airloads on rotorcraft, and the accurate prediction of these loads represents a major challenge to the helicopter technical community. A Specialists' Meeting was organized for the purpose of identifying and assessing recent developments in this field. The primary theme of the meeting was the prediction and experimental verification of the steady and unsteady aerodynamic forces on the rotor blades of modern helicopters and related devices, such as wind turbines. The meeting consisted of four main sessions that addressed recent advances in rotor airloads prediction methods, including the evolution to the present state of the art, the capabilities and limitations of the current methodology, and the specific areas that need further effort.

83-1982
Vibration Characteristics of a Coupled Helicopter Rotor-Fuselage by a Finite Element Analysis
M.J. Rutkowski
NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-A-9053, NASA-TP-2118, USAAVRADCOM-TR-82-A-15, 75 pp (Jan 1983)
AD-A124 533

Key Words: Helicopters, Vibration analysis, Finite element technique

The dynamic coupling between the rotor system and the fuselage of a simplified helicopter model in hover is analytically investigated. Mass, aerodynamic damping, and elastic and centrifugal stiffness matrices are presented for the analytical model; the model is based on a beam finite element, with polynomial mass and stiffness distributions for both the rotor and fuselage representations. For this analytical model, only symmetric fuselage and collective blade degrees of freedom are treated.

83-1983
Laboratory Method for the Analysis of Helicopter Underslung Load Oscillations
V. Poon and J. Soon
Dept. of Aeronautical Engrg., Bristol Univ., UK, Rept. No. BU-273, 115 pp (June 1982)
N83-16303

Key Words: Helicopters, Vibration measurement, Measurement techniques

A reliable method based on strain gage measurements was developed for recording the motions, frequencies and other relevant information; e.g., drag forces of the underslung loads when oscillating in a wind tunnel. The effects of fixed and moving supports on the underslung load motions, and hence on its stability characteristics, were studied at Reynolds number and Froude number of 68,000 and 6.5 respectively. A definite difference in the types of motions of the load is observed. This suggests that a moving support is required if accurate results on the underslung load stability characteristic are to be obtained using the wind tunnel.

BIOLOGICAL SYSTEMS

HUMAN

83-1984
The Differing Annoyance Levels of Rail and Road Traffic Noise
V. Knall and R. Schuemer

Planungsburo Obermeyer, Munchen, Fed. Rep. Germany, J. Sound Vib., 87 (2), pp 321-326 (Mar 22, 1983) 3 tables, 6 refs

Key Words: Traffic noise, Railroad trains, Human response

The results of a study on the relative annoyance by rail or road traffic noise in urban and rural areas are reported. Fourteen areas with rail and road traffic noise with differing levels of loudness were investigated. The annoyance was assessed by means of a questionnaire.

83-1985

Traffic Noise Annoyance and Noise Sensitivity in Persons with Normal and Impaired Hearing

G. Aniansson, K. Pettersson, and Y. Peterson

Audiological Section, ENT Dept., Sahlgren's Hospital, Univ. of Goteborg, Sweden, J. Sound Vib., 88 (1), pp 85-97 (May 8, 1983) 7 figs, 2 tables, 29 refs

Key Words: Traffic noise, Human response

A laboratory study was undertaken to investigate annoyance caused by traffic noise among persons with normal hearing and impaired hearing. The impaired hearing groups are representative of about 10% of the population in Sweden with similar or poorer hearing acuity.

83-1986

Traffic Noise Annoyance and Speech Intelligibility in Persons with Normal and Persons with Impaired Hearing

G. Aniansson and M. Bjorkman

Audiological Section, ENT Dept., Sahlgren's Hospital, Univ. of Goteborg, Sweden, J. Sound Vib., 88 (1), pp 99-106 (May 8, 1983) 4 figs, 2 tables, 20 refs

Key Words: Traffic noise, Human response

Annoyance ratings in speech intelligibility tests at 45 dB(A) and 55 dB(A) traffic noise were investigated in a laboratory study. Subjects were chosen according to their hearing acuity to be representative of 70-year-old men and women, and of noise-induced hearing losses typical for a great number of industrial workers. These groups were compared with normal hearing subjects of the same sex and, when possible, the same age.

83-1987

Comparison Between Train Noise and Road Noise Annoyance During Sleep

M. Vernet

Institut de Recherche des Transports, Centre d'Evaluation et de Recherche des Nuisances, Bron Cedex 69672, France, J. Sound Vib., 87 (2), pp 331-335 (Mar 22, 1983) 4 figs, 2 refs

Key Words: Traffic noise, Human response

Sleep disturbance by train and road noises was studied through in situ physiological recordings on two groups of people submitted to both types of exposure. At different sites acoustical parameters do not influence sleep in the same way. In a quiet place, emergence is an important factor of disturbance, but in a noisy place, noise duration and peak level are acting with interaction to disturb sleep.

83-1988

Pressure L_{eq} and Multiple Noise Sources: A Comparison of Exposure-Response Relationships for Railway Noise and Road Traffic Noise

I.H. Flindell

Inst. of Sound and Vibration Res., Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 87 (2), pp 327-330 (Mar 22, 1983) 1 fig, 5 refs

Key Words: Traffic noise, Railroad trains, Human response

Exposure-response relationships vary with different noise sources when conventional L_{eq} is used as the noise exposure measure. Further, reported annoyance to multiple noise source environments can be higher than predicted by conventional L_{eq}. Pressure L_{eq} is proposed as a superior unified noise index and some evidence is presented in support of this proposal.

83-1989

Reactions to Railway Noise in Denmark

T.V. Andersen, K. Kuhl, and E. Relster

National Agency of Environmental Protection, 29 Strandgade, DK 1401 Kobenhavn K, Denmark, J. Sound Vib., 87 (2), pp 311-314 (Mar 22, 1983) 3 tables, 1 ref

Key Words: Railroad trains, Noise generation, Human response

People's reactions to railway noise were studied along seven Danish railway lines with traffic intensities from 30 to about 300 trains per 24 hours. The relations between the noise level and the extent of annoyance or various kinds of behavior (telephone conversation, TV-listening, opening of windows, sleep, etc.) were found

83-1990

Annoyance Reactions Due to Railway Noise

S. Sorensen and N. Hammar

The National Inst. of Environmental Medicine, Stockholm, Sweden, J. Sound Vib., 87 (2), pp 315-319 (Mar 22, 1983) 5 figs, 1 table, 3 refs

Key Words: Railroad trains, Noise generation, Human response

Social survey studies to assess the presence of general annoyance were made in different areas exposed to railway noise. The results show that an increase in the number of passing trains increases annoyance up to a certain level, after which a leveling off takes place.

83-1991

Source Noise Control Technology for the Workplace

M. Lepor

Naval Ocean Systems Ctr., Airborne Acoustics Branch (Code 5134), San Diego, CA 92152, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 177-184, 15 refs

Key Words: Industrial facilities, Noise generation, Human response

The susceptibility of the human ear to noise-induced damage is now a well-studied and extensively documented topic of occupational health and safety. A considerable amount of investigative work on the magnitude and causes of noise exposure hazards has been performed.

83-1992

Developing Acoustical Criteria for Noise Control Engineering Design

R.N. Fleischman

Paige Hall 3-7, Tufts Univ., Medford, MA 02178, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 115-122, 2 figs, 5 refs

Key Words: Household appliances, Human response, Noise reduction

Acoustic criteria for manufactured products, such as sewing machines, in which the product, the listener and their interaction are considered as a system, is developed.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

83-1993

The Estimation of Coefficient of Linear Damping of Stiff Support According to the Amplitude-Frequency

E. Berger and A. Kelzon

Vibrotechnika, 4 (38), pp 45-51 (1981) 2 figs, 2 refs (In Russian)

Key Words: Supports, Damping

The authors state that damped forced mass vibration amplitude-frequency curves and elastically supported unbalanced rigid rotor amplitude-frequency curves are to some extent similar. Therefore, they evaluate the elastic support damping coefficient in terms of the ratio of experimentally found amplitudes at predetermined points.

83-1994

The Role of Dynamic Structural Stiffness in Successful Vibration Isolation

R.G. DeJong

Cambridge Collaborative, Inc., 225 Third St., P.O. Box 74, Cambridge, MA 02142, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech.,

Cambridge, MA, Mar 21-23, 1983, pp 143-152, 5 figs, 3 refs

Key Words: Vibration isolation

In the design of vibration isolation mounts it is a well established fact that structural stiffness, both above and below the mount, plays an important role in achieving an effective isolation system. This principle can be applied to the more general problem of designing impedance mismatches in a structure to achieve vibration isolation. An analytical treatment of this problem can be developed using a set of mobility equations. This analysis is applied to the case of a vibrating machine mounted on a simple foundation, although the results are generally applicable to any vibration transmission system. The general mobility formulation of the problem is expanded to include more complex conditions such as multiple connection points, multiple degrees of freedom at connections, and an evaluation of the vibrational power transmission across an isolation element. An example of the application of these results is given.

83-1995

Acoustic Performance of a "Reentrant" Axial Fan Intake Silencer

G.C. Tocci and D.H. Sturz

Cavanaugh Tocci Associates, Inc., Natick, MA, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 305-308, 2 figs, 1 table

Key Words: Silencers, Ducts, Fans, Air conditioning equipment, Noise reduction

With its "Space-Gain" air handling unit, a manufacturer of building ventilation equipment components, has pioneered the development of a small, low-cost axial flow fan air handling equipment package that has noise and energy efficiency advantages over conventional air handling units. The merits and unique features of the "Space-Gain" unit are largely in the design of the intake silencer. The reentrant or converging design maintains laminar air flow to the fan blades. This results in increased fan efficiency and decreased turbulence noise at the fan blades.

83-1996

Acoustics of an Obstacle Inside a Reactive Silencer

A. Bostrom and B. Nilsson

Inst. of Theoretical Physics, S-412 96 Goteborg, Sweden, J. Sound Vib., 87 (4), pp 603-619 (Apr 22, 1983) 9 figs, 15 refs

Key Words: Silencers, Ducts, Sound transmission, Sound reflection, Discontinuity-containing media

The transmission and reflection of sound in a cylindrical duct containing several discontinuities is investigated. A building-block method, which gives the transmission and reflection matrices for a complex system from those of the parts, is applied to bifurcations, sudden area changes with or without extended inlets, and spherical obstacles. In some cases the solution can be interpreted in terms of multiple reflections.

83-1997

Centrifugal Blower Noise Reduction Using a Flow Resistive Scroll

D.M. Yeager

IBM Noise Control Lab., Dept. C18, Bldg. 704, P.O. Box 390, Poughkeepsie, NY 12602, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 231-238, 5 figs, 6 refs

Key Words: Absorbers (materials), Acoustic absorption, Cooling systems

This paper describes experiments involving the use of a thin porous plastic material as a sound absorber, which is implemented as an integral part of a small, double-inlet centrifugal blower typically used in computers. The porous material replaces a conventional impermeable scroll and is backed by a sealed air cavity. This configuration yields a reduction in A-weighted sound power level of approximately 2.5 - 3.0 dB(A) over a wide range of cavity volumes with negligible degradation in fan performance.

83-1998

Dynamic Behavior of Particulate Viscoelastic Composites for Sound Absorption

G. Gaunaurd and J. Barlow

Naval Surface Weapons Ctr., Silver Spring, MD, Rept. No. NSWC/TR-82-520, SBI-AD-F500 117, 67 pp (Oct 18, 1982)
AD-A124 272

Key Words: Acoustic absorption, Composite materials, Viscoelastic properties, Granular materials

A general frequency-dependent theory has been developed for the effective material properties (sound speed, attenuation, bulk, dilatational and shear moduli, etc.) of viscoelastic (sound absorbing) substances which contain ensembles of gas-filled cavities -- assumed spherical for this analysis -- of various concentrations and size distributions.

83-1999

Nonlinear Response and Noise Transmission of Double Wall Sandwich Panels

H.-K. Hong

Ph.D. Thesis, Columbia Univ., 106 pp (1982)

DA8307582

Key Words: Acoustic absorption, Noise transmission, Panels, Sandwich structures, Random excitation

An analytical study is presented to predict the nonlinear response of a double wall sandwich panel system subjected to random type loading. Viscoelastic and nonlinear spring-dashpot models are chosen to characterize the behavior of the core. The noise transmission through this panel system into an acoustic enclosure of which the interiors are covered with porous absorption materials is determined. The absorbent boundary conditions of the enclosure are accounted for by a two-step transformation of the boundary effect into a wave equation which governs the acoustic pressure field inside the enclosure.

83-2000

Evaluation of the Guard Rail Energy Absorbing Terminal (G-R-E-A-T) Impact Attenuator

W.C. Walters

Res. and Dev. Section, Louisiana Dept. of Transportation and Dev., Baton Rouge, LA, Rept. No. FHWA/LA-82/160, 24 pp (Sept 1982)

PB83-167080

Key Words: Energy absorption, Guardrails

This report evaluates as many aspects of the Guard Rail Energy Absorbing Terminal (G-R-E-A-T), a vehicle attenuator, as possible. The system was first installed on a particular bridge in September 1979 and was evaluated for three years. No impact occurred during that interval, so an evaluation of impact worthiness could not be assessed. However, installation and its resistance to weather are evaluated.

83-2001

Behavior of a Piping System under Seismic Excitation. Experimental Investigations of a Spatial Piping System Supported by Mechanical Shock Arrestors and Steel Energy Absorbing Devices under Seismic Excitation

S. Schneider, H.M. Lee, and W.G. Godden

Earthquake Engrg. Res. Ctr., Univ. of California, Berkeley, CA, Rept. No. UCB/EERC-82/03, 181 pp (May 1982)

PB83-172544

Key Words: Snubbers, Energy absorption, Piping systems, Nuclear power plants, Seismic excitation

The specimen studied was a half-scale model of a piping system from a nuclear reactor power plant. This was tested in its original design configuration using mechanical shock arrestors (snubbers), and subsequently in a revised configuration using ductile steel energy absorbers. The influence of the snubbers and of different energy absorbers on the dynamic response of the pipe system is discussed; a direct one-to-one replacement of the snubbers by energy absorbers allows a direct comparison of the results.

TIRES AND WHEELS

(Also see No. 2080)

83-2002

The Noise Mechanisms of Cross Groove Tire Tread Pattern Elements

L.J. Oswald and A. Arambages

General Motors Res. Labs., Warren, MI 48090-9055, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 363-374, 9 figs, 8 refs

Key Words: Tires, Truck tires, Noise generation

Experimental studies were conducted to identify and quantify the noise mechanisms of individual elements of commonly used truck tire tread patterns. This paper deals specifically with the results for various forms of the most noisy of tread pattern elements; namely those for cross groove type tread pattern elements. The basic elements of this type of tread pattern are individual cross grooves and lugs. The parameters that were studied are groove depth, angle of the groove relative to the sidewall, groove shape, and the spacing between the two grooves which form a lug. The noise radiated as these parameters were varied one at a time and a discussion of the probable noise mechanisms are presented.

83-2003

The Dynamics of Radially-Guided Threadless Wheels (Zur Dynamik kreisgeführter, spurkranzloser Rader)

G. Strunk

Fortschritt-Berichte VDI-Zt., Reihe 11, No. 50 (1982) 178 pp, 102 figs, 10 tables. Summarized in VDI-Z, 125 (3), p 89 (Feb 1983). Avail: Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany. Price 105, – DM

(In German)

Key Words: Wheels, Interaction: rail-wheel, Antennas, Stick-slip response, Friction, Contact vibration

The classical wheel-track interaction problem is applied to the field of large antennas. In this system, unlike the conventional rail-wheel system, radially guided threadless cylindrical wheels are driven in a radial track at small velocities. In this study the motordynamics of the wheel, including its start-up behavior is investigated. Since rolling conditions are always associated with the slippage of contact surfaces, contact conditions between the wheel and track play a dominating role; therefore, a simple stick-slip law is used to solve the equations of motion. Theoretical results are confirmed by experimental data.

83-2004

Vibration of a Rolling Wheel – Preliminary Results

B. Hemsworth

British Railways Board, Res. and Dev. Div., Railway Technical Ctr., London Rd., Derby DE2 8UP, UK, J. Sound Vib., 87 (2), pp 189-194 (Mar 22, 1983) 9 figs

Key Words: Wheels, Railway wheels, Axial vibration, Noise generation

Preliminary results are presented of the axial vibration of a railway wheel on a vehicle traveling at speeds of up to 100 miles/h. Frequency analysis shows that the wheel response is resonant, at modes of vibration which have been identified from static tests.

83-2005

The Natural and Forced Vibrations of a Wheel Disc

H. Irretier

Institut f. Mechanik, Universität Hannover, Hannover, Fed. Rep. Germany, J. Sound Vib., 87 (2), pp 161-177 (Mar 22, 1983) 13 figs, 15 refs

Key Words: Wheels, Disks (shapes), Natural frequencies, Mode shapes, Forced vibration, Mindlin theory, Noise generation

A mechanical model for a wheel disc with a flat web, based on Mindlin's plate theory, is considered. First the eigenfrequencies and mode shapes of the wheel are calculated with the assumption that a fixed point on the rim is connected elastically to the rail. The forced vibrations of the wheel are then considered under the assumption that a harmonic force acts at the contact surface of the wheel and rail. Results are obtained for the point impedance and the acceleration due to a harmonic force as functions of the frequency of the excitation.

BLADES

(Also see No. 2035)

83-2006

Fatigue Evaluation of WTS-3 Glass Fiber Blade Material

A.F. Blom

Aeronautical Res. Inst. of Sweden, Stockholm, Sweden, Rept. No. FFA-TN-1982-26, 27 pp (Aug 1982)

N83-17901

Key Words: Blades, Turbine blades, Wind turbines, Fatigue life

The fatigue properties of the WTS-3 wind turbine blade material were assessed. Flat test specimens of filament wound material were used for the fatigue tests.

BEARINGS

83-2007

How to Avoid Damage to Unloaded Journal-Bearing Pads

M.L. Adams and E. Makay

Case Western Reserve Univ., Cleveland, OH, Power, 127 (5), pp 47-48 (May 1983) 5 figs, 2 tables, 2 refs

Key Words: Bearings, Tilting pad bearings, Flutter, Steam turbines

Results of a parametric study enabling for the elimination of pad flutter in steam-turbine tilting-pad journal bearings are presented.

83-2008

Bearing Fatigue Investigation 3

A.H. Nahm, E.N. Bamberger, and H. Signer

Aircraft Engine Business Group, General Electric Co., Cincinnati, OH, Rept. No. NASA-CR-168029, 83 pp (May 1982)

N83-17880

Key Words: Bearings, Fatigue life, Rolling contact bearings

The operating characteristics of large diameter rolling-element bearings in the ultra high speed regimes expected in advanced turbine engines for high performance aircraft were investigated. A high temperature lubricant, DuPont Krytox 143 AC, was evaluated at bearing speeds to 3 million DN. Compared to the results of earlier, similar tests using a MIL-L-23699 (Type II) lubricant, bearings lubricated with the high density Krytox fluid showed significantly higher power requirements. Additionally, short bearing lives were observed when this fluid was used with AISI M50 bearings in an air atmosphere.

83-2009

Development of Counter-Rotating Intershaft Support Bearing Technology

W.L. Gamble and R. Valori

Pratt & Whitney Aircraft, West Palm Beach, FL, J. Aircraft, 20 (6), pp 557-563 (June 1983) 16 figs, 1 table, 1 ref

Key Words: Bearings, Rolling contact bearings, Gas turbine engines, Fatigue life

Analytical studies on intershaft cylindrical roller bearings for advanced gas turbine engines configured with counter-rotating shafts showed advantages in fatigue life and internal radial clearance control when the outer ring was mounted on the low-speed rotor and the inner ring on the high-speed rotor. Parametric rig tests on eight bearings showed that the primary drivers on roller end wear were roller-to-guide flange end clearance, outer race preload, and internal radial clearance. Test results showed that concentric roller end wear patterns on all test bearings and varying levels of wear. The performance data were used to improve prediction techniques for bearing heat generation and temperatures.

83-2010

Rolling-Element Fatigue Life of AMS 5900 Balls

R.J. Parker

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TP-2080, 13 pp (Jan 1983)

N83-16758

Key Words: Balls, Fatigue life, Rolling contact bearings

The rolling-element fatigue life of AMS 5900 12.7-mm (½ in.) dia. was determined in five-ball fatigue testers. The 10% life with the warm headed AMS 5900 balls was equivalent to that of AMS 5749 and over eight times that of AISI M-50. The AMS balls fabricated by cold heading had small surface cracks which initiated fatigue spalls where these cracks were crossed by running tracks. The cold-headed AMS 5900 balls had a 10% fatigue life an order of magnitude less than that of the warm headed balls even when failures on the cold headed balls at visible surface cracks were omitted.

GEARS

83-2011

Dynamics of Electromechanical Drive with Regard to Gear Ratio Errors. Steady State Oscillations

A. Andriuškevičius, K. Ragulskis, and T.T. Toločka

Kaunas Politechnical Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 4 (38), pp 19-24 (1981) 2 figs, 1 ref

(In Russian)

Key Words: Gears, Periodic response

Steady state oscillations of the electromechanical drive are investigated when excited by errors of separate gear ratios. Results may be applied for defining the accuracy of drive units.

FASTENERS

83-2012

Comparison of Properties of Joints Prepared by Ultrasonic Welding and Other Means

T. Renshaw, K. Wongwiwat, and A. Sarrantonio

Fairchild Republic Co., Farmingdale, NY, J. Aircraft, 20 (6), pp 552-556 (June 1983) 9 figs, 2 tables, 2 refs

Key Words: Joints (junctions), Welded joints, Ultrasonic techniques, Fatigue life

This is the third in a series of papers on the work being done to develop and evaluate ultrasonic welding as a means for aluminum sheet metal assembly. This paper covers a large-joint testing program that compares the static and fatigue properties of joints prepared by mechanical fastening, adhesive bonding, resistance spotwelding, resistance weldbonding, ultrasonic welding, and ultrasonic weldbonding. Overlap joints 12 in. wide are used for static, monotonic fatigue, and random spectrum fatigue tests. In addition, relative weight and cost factors have been assessed and incorporated into an overall trade study of the various joining methods.

LINKAGES

83-2013

Predicting the Noise Produced by Linkage Mechanisms

S. Dubowsky

Dept. of Mech. Engrg., Rm. 3-451, Massachusetts Inst. of Tech., Cambridge, MA 02139, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 81-90, 10 figs, 10 refs

Key Words: Linkages, Noise prediction

A dynamic acoustical modeling technique, which combines recent dynamic models of high speed linkage systems with classical acoustic modeling techniques, is applied to a linkage system which has both flexible members and an adjustable clearance connection. The noise generated by this system is predicted analytically and compared to experimental results. Excellent correlation of the analytical noise with experimentally measured values validates the modeling technique.

VALVES

83-2014

A Comparative Study of Sound Level Prediction Methods for Control Valves

A.K. Shea

1509 High St., Erie, PA 16509, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 21-25, 2 tables, 9 refs

Key Words: Valves, Noise prediction

The designer of steam power and petrochemical plants must be able to accurately predict the noise generated by control valves, which are integral devices in such plants. Recognizing that predicting control valve noise is a systems problem in which there is often interaction between the source (control valve) and the path (surrounding area), there are several alternatives available to reduce noise, such as heavier pipe walls, lagging, barriers, silencers, or quiet trims. The engineer must have at his disposal a useful and accurate method of predicting noise generated by control valves in order to make such decisions. Several valve manufacturers in England, America, and Europe have developed methods for predicting valve noise. These methods are generally based on empirical data. The main objective of the investigation on which this paper is based was to compare the calculated noise predicted by each of several methods to demonstrate whether the techniques consistently predict similar noise levels for the same conditions or whether there is some variation from one technique to another.

83-2015

Coefficients and Factors Relating to the Aerodynamic Sound Level Generated by Throttling Valves

H.D. Baumann

H.D. Baumann Associates, Ltd., 35 Mirona Rd., Portsmouth, NH 03801, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 27-40, 4 figs, 13 refs

Key Words: Valves, Noise prediction

Valve noise estimating methods published by major valve manufacturers are considered to be reasonably accurate due to periodic updating. However, their use is limited for general applications by other vendors and users due to their exclusive applicability to certain specific and proprietary valve styles and their generally empirical nature. The purpose of this paper is to propose pressure recovery coefficient modified acoustical efficiency factors applicable to all single stage orificial throttling valves, which may be used for the accurate prediction of aerodynamic sound. Such coefficients are also used to express the degree of confinement of sound producing jets.

83-2016

Acoustical Design Considerations for Low-Noise Control Valves

S.J. Boyle

McGraw-Edison Co., Norwood, MA 02062, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 41-50, 3 figs, 11 refs

Key Words: Valves, Noise generation, Design techniques

Aerodynamic noise generation is an inherent by-product of the compressible fluid throttling process in valves. Due to continuing and increasingly stringent environmental and in-plant noise requirements, valve noise is a major concern. When noise levels exceed acceptability criteria the most cost effective approach is often "source treatment" using a specially designed low noise valve. This paper presents relevant theoretical, empirical and practical factors and a new valve design.

83-2017

Control Valve and Regulator Noise Generation, Propagation, and Prediction – A Review

G. Reethof

The Pennsylvania State Univ., 213 Engrg. Unit E, University Park, PA 16802, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 9-20, 5 figs, 24 refs

Key Words: Valves, Noise generation, Sound propagation, Noise prediction, Piping systems

The processes associated with noise from valves and the associated piping can be broken down into four interrelated elements: 1) the noise generation processes just downstream of the throttling elements; 2) the development of the acoustic field inside the piping downstream of the valves; 3) the excitation of the pipe wall vibrations; and 4) the radiation of the sound into the space surrounding the downstream pipe. Each of the four elements listed is discussed in detail.

STRUCTURAL COMPONENTS

CABLES

83-2018

Report on Experimental Observation of Galloping Behaviour in 8-Bundled Conductors

K. Tsujimoto, H. Iisaka, K. Shimojima, H. Kubokawa, T. Okumura, and K. Fujii

Kansai Electric Power Co., Osaka, Japan, IEEE Trans., Power Apparatus Syst., PAS-102 (5), pp 1193-1201 (May 1983) 20 figs, 6 refs

Key Words: Transmission lines, Galloping

In Japan recently the necessity for large scale electric power transmission over long distances has increased due to difficulties in obtaining sites for the expansion of the existing electric power system. In response to this need, technical development on transmission lines with low inductance and UHV transmission has been carried out. This report describes the results obtained from the observation and evaluation of galloping in two field test lines using large diameter 8-bundled conductors.

83-2019

Wind Tunnel Measurements of the Power Imparted to a Model of a Vibrating Conductor

C.B. Rawlins

Alcoa Conductor Products Co., Massena, NY 13662, IEEE Trans., Power Apparatus Syst., PAS-102 (4), pp 963-971 (Apr 1983) 8 figs, 31 refs

Key Words: Transmission lines, Wind-induced excitation, Wind tunnel testing

Predicting the severity of aeolian vibration of overhead conductors requires knowledge of the damping in the span and of the power that the wind can supply to it. There is considerable dispersion in the published data on wind power input. New measurements were made, using a novel test arrangement, in an effort to develop more reliable information. The tests covered a broad range of wind speeds, above and below that at which power input is greatest, to lay a basis for development of methods for dealing with the effects of turbulence in natural winds. Correlation of the new results with previous data is reviewed in depth.

83-2020

Vortex Shedding from a Vibrating Cable with Attached Spherical Bodies in a Linear Shear Flow

R.D. Peltzer

Ph.D. Thesis, Virginia Polytechnic Inst. and State Univ., 182 pp (1982)

DA8310713

Key Words: Cables, Fluid-induced excitation, Vortex-induced vibration, Vortex shedding

Marine cables often comprise an integral part of a larger structural system, such as an offshore drilling platform. They are also used to support marker buoys, as well as anchored or towed instrument arrays. Consequently, the resonant flow-induced oscillation of these cables, caused by vortex shedding, is extremely undesirable because of the associated damaging phenomena. The present study, which employs hot wire anemometry as the principal investigative tool, was undertaken to examine the behavior in the near wake of a flexible, helically wound, high aspect ratio (L/d = 107) marine cable in a linear shear flow (steepness parameter β = 0.0053) at centerline Reynolds numbers between $2.0 \times 10^3 \leq Re_c \leq 4.2 \times 10^4$.

BARS AND RODS

(See No. 2045)

BEAMS

(Also see No. 2045)

83-2021

Dynamic Analysis of Geometrically Nonlinear Truss Structures

S. Abrate and C.T. Sun

School of Aeronautics and Astronautics, Purdue Univ., West Lafayette, IN 47907, Computers Struc., 17 (4), pp 491-497 (1983) 9 figs, 1 table, 16 refs

Key Words: Beams, Trusses, Large amplitudes, Matrix methods, Equivalent continuum method

Beam-like truss structures undergoing large deflections when subjected to static and dynamic loadings are studied by using the matrix method and equivalent continuum models. For the matrix method, an incremental procedure with equilibrium iterations are used. Equivalent continuum beam models are derived based on the properties of a typical substructure of the truss. Solutions obtained by using both methods are compared for a number of examples.

83-2022

On the Shear Coefficient in Timoshenko's Beam Theory

J.J. Jensen

Dept. of Ocean Engrg., The Technical Univ. of Denmark, 2800 Lyngby, Denmark, J. Sound Vib., 87 (4), pp 621-635 (Apr 22, 1983) 8 figs, 1 table, 15 refs

Key Words: Beams, Timoshenko theory, Transverse shear deformation effects, Ship hulls, Natural frequencies

Some existing formulations for the shear coefficient in Timoshenko's beam theory are discussed, especially through evaluation of the accuracy to which natural frequencies of simply supported, prismatic, thin walled beams can be obtained. The main conclusion drawn is that if a consistent expression for the shear coefficient is used in Timoshenko's beam theory, then very high accuracies can be expected for the natural frequencies, even for wavelengths of the same magnitude as the transverse dimension of the beam.

CYLINDERS

83-2023

Galloping of Bluff Bodies

W.C. Cheung and W.C. Man

Dept. of Aeronautical Engrg., Bristol Univ., UK, Rept. No. BU-272, 81 pp (June 1982)

N83-16302

Key Words: *Cylinders*, Galloping

Six slender square section cylinders, each with different corner radii, were investigated statically and dynamically in smooth and turbulent flows. By progressively rounding off the four corners of a square section, the drag force is reduced substantially, particularly in smooth flow. The validity of quasi-steady theory, using the experimental aerodynamic coefficients, to explain the observed aeroelastic instability of bluff cylinders in a uniform stream is justified by the good agreement between the theoretical predictions and the dynamic test data, when only plunging oscillation is allowed.

FRAMES AND ARCHES

83-2024

Natural Frequencies of In-Plane Vibration of Arcs

T. Irie, G. Yamada, and K. Tanaka

Hokkaido Univ., Kita-13, Nishi-8, Sapporo, 060

Japan, J. Appl. Mech., Trans. ASME, 50 (2), pp 449-452 (June 1983) 1 fig, 2 tables, 18 refs

Key Words: Arches, Natural frequencies

The natural frequencies of in-plane vibration are presented for uniform arcs with circular cross section under all combinations of boundary conditions.

83-2025

Forced Motion of a Simple Frame Subjected to a Moving Force

C.K. Karaolides and A.N. Kounadis

Dept. of Civil Engrg., Natl. Tech. Univ., Athens, Greece, J. Sound Vib., 88 (1), pp 37-45 (May 8, 1983) 4 figs, 1 table, 9 refs

Key Words: Frames, Moving loads

The dynamic response of a simple two-member frame subjected to a constant force moving across its girder with a constant velocity is discussed. After determining the orthogonality condition for the frame as well as its eigenfrequencies and normal modes, one can easily establish the dynamic response of the frame. Dynamic and static influence lines of characteristic displacements and internal forces are assessed for two different velocities of the moving force. Comparisons between dynamic and static solutions indicate that the dynamic effect of the moving load may be considerable.

PANELS

(Also see No. 1999)

83-2026

Impact Damage Effects of Fatigue of Composite Materials

W.G.J. Thart and R.J.H. Wanhill

Natl. Aerospace Lab., Amsterdam, The Netherlands, Rept. No. NLR-MP-82011-U, 18 pp (Mar 1982) N83-17605

Key Words: Panels, Composite structures, Sandwich structures, Fatigue life

The effects of low velocity impact damage on tension compression fatigue of composite sandwich panels were investigated. The panels consisted of carbon epoxy face sheets with a 9 mm thick NOMEX honeycomb core. Impact damage was mainly face sheet delamination. Fatigue resulted in propagation of delamination damage, leading to face sheet/core debonding and fiber breakage in some cases. Damage propagation occurred at relatively low fatigue stresses and from barely visible impacts. The methods of damage detection are discussed.

83-2027

The Effect of a Normal Shock on the Aeroelastic Stability of a Panel

M.H. Williams

School of Aeronautics and Astronautics, Purdue Univ., West Lafayette, IN 47907, J. Appl. Mech., Trans. ASME, 50 (2), pp 275-282 (June 1983) 9 figs, 4 refs

Key Words: Panels, Shock excitation, Aeroelasticity

The effect of a standing shock wave on the static and dynamic aeroelastic stability of a flexible panel is investigated using a linear structural and aerodynamic theoretical model. It is found that the shock is generally stabilizing. The lowest critical dynamic pressures are associated with shock positions downstream from the panel, where the panel is uninfluenced by the shock.

PLATES

(Also see Nos. 1976, 2045)

83-2028

Buckled Plate Vibrations, Large Amplitude Vibrations, and Nonlinear Flutter of Elastic Plates Using High-Order Triangular Finite Elements

An-Dong Han

Ph.D. Thesis, Purdue Univ., 112 pp (1982) DA8310758

Key Words: Plates, Free vibration, Large amplitudes, Flutter, Finite element technique

A high-order triangular membrane finite element is combined with a fully conforming triangular plate bending element to solve the geometrically nonlinear problems of plates where the membrane and flexural behavior are coupled and the effect of the inplane boundary conditions is as significant as the flexural boundary conditions. Each of the three orthogonal displacement components is represented by a two-dimensional polynomial of quintic order with no bias against one or the other giving the element a total of 54 degrees of

freedom. The nonlinear stiffness matrices are formulated and an iterative procedure is used. Examples include the plane stress analyses of a parabolically loaded square plate, large deflections of a square plate under lateral pressure, postbuckling of a square plate, linear free vibration of a square plate with and without inplane stresses. Various flexural and inplane boundary conditions are considered.

83-2029

Effect of Uniform Flow on the Dynamics and Acoustics of Force-Excited Infinite Plates

D.J. Atkins

Admiralty Marine Technology Establishment, Teddington, UK, Rept. No. AMTE(N)/TM82087, DRIC-BR-86583, 56 pp (Dec 1982)

AD-A124 576

Key Words: Plates, Harmonic excitation, Periodic excitation

Formulae are obtained for the time-harmonic steady-state plate displacement, acoustic pressure and particle velocities. The far-field pressure is obtained for a stationary phase approximation, and two separate formulations are used to define a time-averaged acoustic intensity vector. The stability of a line-excited plate is examined using both a steady-state approach and a causal approach which is able to distinguish between absolute and convective instability. Some numerical results are presented for a steel plate vibrating in water.

83-2030

Discrete and Non-Discrete Mixed Methods Applied to Eigenvalue Problems of Plates

F. Fujii and T. Hoshino

Dept. of Civil Engrg., Gifu Univ., Gifu, Japan, J. Sound Vib., 87 (4), pp 525-534 (Apr 22, 1983) 2 figs, 3 tables, 15 refs

Key Words: Plates, Eigenvalue problems

A mixed variational formulation for eigenvalue problems of plates is presented. Spline functions with multiple nodes are used to interpolate the displacement and moment fields. The solution procedure can be applied in either discrete or non-discrete forms. In contrast with displacement methods, the specified boundary conditions can be considered very easily by introducing multiplicity in the boundary nodes. Numerical examples include buckling and free vibration of rectangular plates with in-plane loading and/or elastic foundations. The accuracy of the results obtained and the superiority of the mixed methods presented to conventional displacement approaches are discussed.

SHELLS

83-2031

Seismic Response of Prestressed and Ring-Stiffened Liquid-Filled Tanks

S.C. Lee

Ph.D. Thesis, Univ. of Massachusetts, 217 pp (1983)

DA8310308

Key Words: Shells, Tanks (containers), Fluid-filled containers, Seismic excitation, Modal analysis

The finite element method based on a variational procedure of formulation is used to develop equations of motion of the shell subject to prestress. The mass and stiffness matrices are obtained through extensive use of matrix methods. Following a numerical approach of eigenvalue analysis for determining the frequencies and the corresponding mode shapes, the problem of small amplitude elastic response of a prestressed (axisymmetric) liquid-filled tank to an artificial earthquake excitation is studied by the modal analysis approach. The prestressing (meridional, circumferential or radial) may be prescribed in any distribution along the meridian of the shell. The study of free vibrations of prestressed shells also includes restricted cases of follower effects of normal pressures on the natural frequencies of the shell. Attention is also devoted to the study of the vibration response of ring-stiffened tanks.

83-2032

Elastic-Plastic Fracture of Cylindrical Shells Containing Part-Through Circumferential Cracks

H.A. Ezzat

Ph.D. Thesis, Lehigh Univ., 235 pp (1983)

DA8306369

Key Words: Shells, Cylindrical shells, Crack propagation, Discontinuity-containing media

The problem of fatigue crack propagation and ductile fracture in a cylindrical shell containing a macroscopic circumferential flaw is considered in this study. The main interest is in applications to line pipes under secondary axial stresses. The stress intensity factor for the part-through crack used in analyzing and correlating the fatigue crack propagation rate is obtained by using a line spring model in conjunction with Reissner's shell theory. To analyze the ductile fracture instability and to correlate the experimental and theoretical results the crack mouth opening displacement is used as the parameter.

83-2033

Static and Dynamic Buckling of Pressure-Loaded, Ring-Stiffened Cylindrical Shells

G.J. Simitses and I. Sheinman

Georgia Inst. of Tech., Atlanta, GA, J. Ship Res., 27 (2), pp 113-120 (June 1983) 5 figs, 1 table, 36 refs

Key Words: Shells, Cylindrical shells, Dynamic buckling, Critical loads

The analysis of imperfect, stiffened, thin circular shells, subjected to suddenly applied pressure, is presented. A solution scheme for the complete (including post-limit point behavior) static analysis is described. The concept of dynamic stability is discussed for suddenly loaded structures. In addition, a fairly complete review of the reported works on the subject is presented. Results are presented for a ring-stiffened geometry. These include critical dynamic loads, critical static loads (limit point loads), as well as minimum post-limit point loads.

83-2034

Flow in a Torsionally Oscillating Filled Cylinder

C.F. Schafer

George C. Marshall Space Flight Ctr., NASA, Huntsville, AL, Rept. No. NASA-TP-2115, 20 pp (Jan 1983)

N83-16674

Key Words: Shells, Cylindrical shells, Fluid-filled containers, Torsional vibration

The flow of a liquid in a completely filled cylinder undergoing torsional oscillations about its longitudinal symmetry axis was studied analytically and experimentally. The objective of the studies was to determine the efficacy of the torsional oscillations in mixing the confined liquid. Flow was found to be confined primarily to toroidal cells at the ends of the cylinder. Cell thickness was about equal to the cylinder radius. The use of baffles at the end walls was shown to enhance the mixing process.

83-2035

Vibrations of Cantilevered Circular Cylindrical Shells: Shallow Versus Deep Shell Theory

J.K. Lee, A.W. Leissa, and A.J. Wang

Dept. of Engrg. Mechanics, Ohio State Univ., Columbus, OH 43210, Intl. J. Mech. Sci., 25 (5), pp 361-383 (1983) 9 figs, 9 tables, 23 refs

Key Words: Shells, Cylindrical shells, Cantilever shells, Rotor blades (turbomachinery), Ritz method, Natural frequencies, Mode shapes

Free vibrations of cantilevered circular cylindrical shells having rectangular planforms are studied in this paper by means of the Ritz method. The deep shell theory of Novozhilov and Goldenveizer is used and compared with the usual shallow shell theory for a wide range of shell parameters. A thorough convergence study is presented along with comparisons to previously published finite element solutions and experimental results. Accurately computed frequency parameters and mode shapes for various shell configurations are presented.

83-2036

Simplified Equations and Solutions for the Vibration of Orthotropic Cylindrical Shells

W. Soedel

School of Mech. Engrg., Purdue Univ., West Lafayette, IN 47907, J. Sound Vib., 87 (4), pp 555-566 (Apr 22, 1983) 5 figs, 14 refs

Key Words: Shells, Cylindrical shells, Orthotropism

Starting with Love type equations of motion for orthotropic circular cylindrical shells, the theory is simplified by assumptions similar to those in the Donnell-Mushtari-Vlasov development for isotropic shells. Closed form solutions for simply supported cases are then obtained. Results of two example cases are compared with finite element results and are shown to agree well. It is argued that this simplified approach allows easy assessment of the influence of design parameter changes.

83-2037

Dynamic Elasto-Plastic Response of Shells in an Acoustic Medium -- EPSA Code

R.S. Atkatsh, M.P. Bieniek, and M.L. Baron

Weidlinger Associates, New York, NY, Intl. J. Numer. Methods Engrg., 19 (6), pp 811-824 (June 1983) 7 figs, 13 refs

Key Words: Shells, Elastic properties, Plastic properties, Computer programs

A nonlinear, large deflection, elasto-plastic finite element code (EPSA) has been developed for the analysis of shells in an acoustic medium subjected to dynamic loadings. The nonlinear equations of shells are discretized with the aid of a finite difference/finite element method based upon the

principle of virtual work. The resulting system of equations contains the nodal displacements as the generalized co-ordinates of the problem. The integration in time of the equations of motion is done explicitly via a central difference scheme.

PIPES AND TUBES

83-2038

Dynamics of a Cluster of Flexibly Interconnected Cylinders. Part 1: In Vacuum

M.P. Paidoussis, K.N. El Barbir, M.R. Genadry, and J.-P. Chaubernard

Dept. of Mech. Engrg., McGill Univ., Montreal, Quebec, Canada, J. Appl. Mech., Trans. ASME, 50 (2), pp 421-428 (June 1983) 7 figs, 3 tables, 10 refs

Key Words: Tube arrays

This paper presents an analytical model for the dynamics of a cluster of flexible cylinders, the extremities of which are structurally interconnected; e.g., through end plates or other kinds of structural connectors. These connectors are modeled by sets of translational and rotational springs, such that resistance to both in-plane and out-of-plane deformation of the connectors is fully taken into account. The dynamics of the system in vacuum is examined, especially the effect of varying the different spring stiffnesses on the system eigenfrequencies. This provides a reference base and the necessary analytical tools for the study of the system in axial flow, which is presented as Part 2 of this work.

83-2039

Dynamics of a Cluster of Flexibly Interconnected Cylinders. Part 2: In Axial Flow

M.P. Paidoussis, J.-P. Chaubernard, M.R. Genadry, and K.N. El Barbir

McGill Univ., Montreal, Quebec, Canada, J. Appl. Mech., Trans. ASME, 50 (2), pp 429-435 (June 1983) 9 figs, 5 refs

Key Words: Tube arrays, Fluid-induced excitation

The dynamical characteristics are discussed of a cluster of cylinders, the extremities of which are interconnected by beam-like connectors, modeled here by sets of linear springs as formulated in Part I of this study; resistance to both in-plane and out-of-plane deformation of the connectors is taken into account. The cylinders are subjected to axial flow, and hydrodynamic coupling in cylinder motions is taken into account. The system eigenfrequencies and modal shapes are calculated for different conditions of structural and hydrodynamic coupling. The effect of increasing flow on the dynamics of the system is also studied, up to and beyond the threshold of fluid-elastic instabilities.

83-2040

Heat Exchanger Tube Vibrations. 1970 - March, 1983 (Citations from the Engineering Index Data Base)

NTIS, Springfield, VA, 116 pp (Mar 1983)
PB83-861864

Key Words: Tube arrays, Heat exchangers, Vibration analysis, Bibliographies

This bibliography contains 120 citations concerning design, fabrication, and vibration studies of heat exchanger tubes. Basic excitation mechanisms of tube vibrations, effect of heat exchanger configurations, preoperational testing of tubes, and vibration detection techniques are discussed. Model studies and computer simulation techniques are presented.

83-2041

Heat Exchanger Tube Vibrations. 1976 - March, 1983 (Citations from the Energy Data Base)

NTIS, Springfield, VA, 74 pp (Mar 1983)
PB83-861971

Key Words: Tube arrays, Heat exchangers, Vibration analysis, Bibliographies

This bibliography contains 70 citations concerning design, fabrication, and testing of heat exchanger tubes and tube bundles for vibrational considerations. Basic excitation mechanisms of tube vibrations, effects of heat exchanger configurations, preoperational testing of tubes, and vibration detection techniques are discussed. Mathematical models and computer simulation techniques are presented.

83-2042

Theoretical and Experimental Study of Fracture in Pipelines Containing Circumferential Flaws

F. Erdogan

Dept. of Mechanical Engrg. and Mechanics, Lehigh

Univ., Bethlehem, PA, Rept. No. DOT-RSPA-DMA-50/83/3, 481 pp (Aug 1982)
PB83-159749

Key Words: Pipelines, Fatigue life, Crack propagation

This report presents the theoretical and experimental results of a four year research program on the fatigue crack propagation and ductile fracture in pipelines and relatively thin-walled cylindrical containers. The objectives of the program were to identify the possible modes of fracture failure in pipelines and pressurized cylinders containing a circumferential flaw, to review the field and to develop the appropriate theoretical models for various phases of the fatigue and fracture in pipelines, and to carry out the necessary analytical investigations in order to develop the tools needed for the application of these models, and to design and perform an experimental research program in order to test the validity and limitations of the theoretical models.

DUCTS

(Also see No. 1995)

83-2043

Sound Power Radiated by Round Spiral Ductwork

J.G. Lilly

Towne, Richards & Chaudiere, Inc., 105 N.E. 56th St., Seattle, WA 98105, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 297-304, 7 figs, 1 table, 4 refs

Key Words: Ducts, Sound power levels, Air conditioning equipment

To date there is a void in the literature providing a simple, reasonably accurate technique for computing noise levels radiated by HVAC ductwork. "Breakout" as it is sometimes referred, is the phenomenon of air-borne in-duct sound power radiating through the walls of the duct into the surrounding environment. This paper is based on a set of measurements conducted with double wall, acoustically lined spiral round ductwork 0.3 m (12"), .61 m (24"), and .91 m (36") in diameter. The purpose of the paper is to present a simple technique for predicting breakout which can be implemented in any duct system, and present measured values of the equivalent transmission loss for full-sized spiral ductwork which can be used to predict the radiated sound power levels in actual HVAC systems.

83-2044

A Finite Element Approach for Predicting Nozzle Admittances

R.K. Sigman and B.T. Zinn

School of Aerospace Engrg., Georgia Inst. of Tech., Atlanta, GA 30332, J. Sound Vib., 88 (1), pp 117-131 (May 8, 1983) 7 figs, 1 table, 23 refs

Key Words: Nozzles, Mechanical admittance, Finite element technique, Elastic waves, Sound waves

A finite element method is used to predict the admittances of axisymmetric nozzles. It is assumed that the flow in the nozzle is isentropic and irrotational, and the disturbances are small so that linear analyses apply. An approximate, two dimensional compressible model is used to describe the steady flow in the nozzle. The propagation of acoustic disturbances is governed by the complete linear wave equation. The differential form of the acoustic equation is transformed to an integral equation by using Galerkin's method, and Green's theorem is applied so that the acoustic boundary conditions can be introduced through the boundary residuals. The boundary conditions are described for both straight and curved sonic lines.

BUILDING COMPONENTS

83-2045

On the Dynamic Fracture of Bars, Beams, and Plates

C. Levy

Ph.D. Thesis, Stanford Univ., 187 pp (1983)
DA8307180

Key Words: Bars, Beams, Plates, Crack propagation

The investigation of the dynamic fracture of bars, beams, and plates under various loading conditions was undertaken in two distinct areas: the numerical solution of crack propagation problems using a finite difference code and the analytical solution of some beam fracture problems using several one-dimensional models. The motion of the crack tip, for the double cantilever beam (DCB) specimen, and for the single edge notch (SEN) specimen, was obtained for various loading conditions by means of a recently proposed finite difference code. The numerical results for the DCB model were compared with experimental results and found to be in good numerical and qualitative agreement.

83-2046

Mathematical Model for the Response of Masonry Walls to Dynamic Excitations

H. Sucuoglu, Y. Mengi, and H.D. McNiven

Earthquake Engrg. Res. Ctr., Univ. of California, Berkeley, CA, Rept. No. UBC/EERC-82/24, NSF/CEE-82069, 135 pp (Nov 1982)
PB83-169011

Key Words: Walls, Masonry, Mathematical models, Seismic excitation, Earthquakes

The study involves three stages: experimental observations, choice of the form for a mathematical model, and optimization analysis. The masonry wall specimens were subjected to simulated earthquake ground motions, and horizontal and vertical periodic excitations. Evaluation of the experimental data indicates that the first two modal frequencies are close to each other.

ELECTRIC COMPONENTS

MOTORS

83-2047

Nonlinear Transient Finite Element Field Computation for Electrical Machines and Devices

S.C. Tandon, A.F. Armor, and M.V.K. Chari
General Electric Co., Schenectady, NY, IEEE Trans., Power Apparatus Syst., PAS-102 (5), pp 1089-1095 (May 1983) 20 figs, 3 tables, 24 refs

Key Words: Motors, Electromagnetic properties, Transient response, Finite element technique

This paper describes the procedure for analyzing nonlinear transient electromagnetic phenomena in electrical machines and devices with the finite element method. Two time integration methods are used which are based on an implicit forward difference scheme and the Crank-Nicholson method. The quasilinearization of the nonlinear matrix equation is handled by a simple chord iteration method in the former and the Newton-Raphson scheme in the latter. The associated variational expressions for the time-dependent diffusion equation are obtained in terms of energy-related functionals. The paper includes illustrative examples of application of the methods to one- and two-dimensional time-dependent eddy current problems in a conducting slab, a rotating machine under asynchronous operation, and a three-phase bus-bar enclosure.

83-2048

Dynamics of Vibromotors with Annular Actuators

L. Patašiene and K. Ragulskis
Kaunas Politechnic Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 4 (38), pp 159-161 (1981) 2 figs, 3 refs
(In Russian)

Key Words: Actuators, Motors

The dynamics of undulating vibromotors with piezoelectric annular actuators is investigated. Differential equations for the determination of speed of rotation of the vibromotor are developed and the effect of friction on the vibromotor is studied.

83-2049

Noise Sources in Electric Motors (Airborne)

D.H. Cashmore
Westinghouse Electric Corp., Heavy Industry Motor Div., Round Rock, TX 78664, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 311-318

Key Words: Motors, Motor noise, Noise prediction

Various noise sources to be considered in noise prediction of AC squirrel cage induction motors are discussed.

83-2050

Natural Frequencies and Vibration Behaviour of Motor Stators

S. Watanabe, S. Kenjo, K. Ide, F. Sato, and M. Yamamoto
Toshiba Corp., Yokohama, Japan, IEEE Trans., Power Apparatus Syst., PAS-102 (4), pp 949-956 (Apr 1983) 14 figs, 7 tables, 6 refs

Key Words: Stators, Natural frequencies, Motors

In order to reduce electromagnetic acoustic noise in motors, it is essential to understand the vibration behavior of the stators so as to prevent resonance between the electromagnetic forces and the stators. This paper presents an assessment of the effects of teeth, windings, impregnation and wedges on the natural frequencies and vibration response of stators on the basis of experiments and simulation through

numerical computation of the natural frequencies and vibration response of ring- and segmented-core stators having totally impregnated formed coils.

83-2051

Stability Synthesis of Control System in Current Fed Inverter Driven Induction Motor

R. Ueda, T. Sonoda, T. Ito, T. Mochizuki, and T. Irisa
Kyushu Inst. of Tech., Kitakyushu, Japan, IEEE Trans., Power Apparatus Syst., PAS-102 (1), pp 171-179 (Jan 1983) 15 figs, 15 refs

Key Words: Motors, Control equipment

This paper presents a new method of synthesizing a stabilizing control system in a current fed inverter driven induction motor. The method is focused on rotor dynamics and a concept of damping torque coefficient is introduced concerning the electrical torque. Analytical results are verified with laboratory field tests.

83-2052

AC Induction Motor Torsional Vibration Consideration – A Case Study

J.H. Holdrege, W. Subler, and W.E. Frasier
Reliance Electric Co., 24701 Euclid Ave., Cleveland, OH 44117, IEEE Trans., Indus. Appl., IA-19 (1), pp 68-73 (Jan/Feb 1983) 15 figs, 11 refs

Key Words: Torsional vibration, Motors

Much has been written on the application of high-speed (3600 r/min) motors to pumps and compressors relative to vibration and lateral critical speeds. A reciprocating compressor coupled to an induction motor is a complex torsional system and can present a more complex set of problems to the equipment suppliers because of the wider range of forcing frequencies present. The problems encountered on a specific application with the objective of developing guidelines to be used to avoid similar system torsional problems on the application of induction motors to reciprocating equipment are discussed.

83-2053

Optimal Design of an Overall Controller of Saturated Synchronous Machine under Different Loading

A.I. Saleh, M.K. El-Sherbiny, and A.A.M. El-Gaafary
Electrical Engrg. Dept., Assiut Univ., Egypt, IEEE Trans., Power Apparatus Syst., PAS-102 (6), pp 1651-1657 (June 1983) 8 figs, 1 table, 10 refs

Key Words: Synchronous motors, Optimization, Pontryagin's principle

The main purpose of this paper is to design a feedback system that optimizes the dynamic response of the system. Such a system should be stable for any small disturbance. Pontryagin's maximum principle, which gives the solution for the optimal linear regulator problem through the eigenvector method, is applied. The system consists of a synchronous machine connected to an infinite bus through a transmission line. The effect of two control signals fed to the voltage regulator and the mechanical system is investigated. The effect of machine saturation on dynamic response is also included.

83-2054

Transient Stability of Synchronous Generators with Two-Axis Slip Frequency Excitation

M.S. Morsy, H.H. Amer, M.A. Badr, and A.M. El-Serafi
Electrical Engrg. Dept., Ain-Shams Univ., Egypt, IEEE Trans., Power Apparatus Syst., PAS-102 (4), pp 852-858 (Apr 1983) 14 figs, 5 refs

Key Words: Synchronous motors, Transient response

This paper presents a study of the transient stability characteristics of two-axis synchronous generators as affected by its excitation control and input governing systems when they operate synchronously before the occurrence of the disturbance. The results show that such unregulated two-axis synchronous generators with slip frequency excitation have superior transient stability limits compared with conventional alternators. These generators, when properly controlled, can have also improved transient stability characteristics compared with regulated conventional synchronous generators. The improvement realized depends on the optimal choice of the control system and parameters.

83-2055

The Application of Bond Graphs to Electrical Machinery and Power Engineering

K. Sirivadhna, E.F. Richards, and M.D. Anderson
Univ. of Missouri-Rolla, IEEE Trans., Power Appa-

ratus Syst., PAS-102 (5), pp 1176-1184 (May 1983) 19 refs

Key Words: Bond graph technique, Synchronous motors

The bond graph technique is a modeling procedure where emphasis is placed on the flow of power and energy in a system. Through specific digital simulation programs, associated output equations and system dynamic response are directly obtainable from the bond graphs. The purpose of this paper is three-fold: to develop interest in the bond graph modeling technique in power engineering, to develop bond graph models for typical synchronous and induction machines which are not as well developed in the literature as are the graphs of mechanical components, and to complete some of the missing links in the development of bond graphs for electromechanical machines.

GENERATORS

83-2056

Stresses on Generators Feeding HVDC Link Inverter Bus

H.L. Nakra, L.X. Bui, D. Doulier, and P. Czech

Hydro-Quebec, Montreal, Canada, IEEE Trans., Power Apparatus Syst., PAS-102 (6), pp 1633-1638 (June 1983) 5 figs, 5 refs

Key Words: Generators, Torsional vibration

Generators connected at the inverter end of an HVDC link are subject to special problems of power reversal on load shedding and oscillatory torques resulting from resonance with the filters. Results of simulation studies of a real system where this can occur are presented.

TRANSFORMERS

83-2057

The French Experience in Sound Proofing of High Power Transformers

B. Jost and F. Laville

Electricite de France, Departement Acoustique, F 92141 CLAMART - CEDEX, France, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 319-322

Key Words: Transformers, Noise reduction

The increasing demand for electricity and the economical need to bring the high voltage network close to the users lead Electricité de France to increase the unit power per transformer as well as the number of transformers per station. As a result transformer stations caused community reaction although modern transformers showed reduced noise rating. Because transfomer noise is easily recognized, sound reduction measures were taken. Isolated sound proofing measures on already operating equipment rapidly gave birth to general guidelines that made it possible to eliminate the noise problem at the design stage.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

(Also see Nos. 1935, 1936, 1949, 1995, 2067, 2087, 2088, 2129, 2130, 2131)

83-2058

Noise Source Identification and Reduction in a Chocolate Plant

J. Nicolas, R. Benoit, and S. Sauve

Université de Sherbrooke, Génie mecanique Sherbrooke, Quebec, Canada J1K 2R1, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 339-342, 2 figs, 3 refs

Key Words: Industrial facilities, Noise source identification, Noise reduction

An investigation of dominant noise sources in a chocolate plant shows that frequent impacts are a major problem. Experimental test data and appropriate noise reduction techniques are described.

83-2059

Some Simple Formulae for Normal Mode Wave Numbers, Cutoff Frequencies, and the Number of Modes Trapped by a Sound Channel

D.D. Ellis

Defence Res. Establishment Atlantic, Dartmouth, Nova Scotia, Rept. No. DREA-TM-82/0, 16 pp (Nov 1982)
AD-A124 948

Key Words: Underwater sound, Sound propagation

In this paper formulae based on exact and WKB solutions are presented for the number of modes trapped in some simple sound channels and for the wave numbers and cutoff frequencies associated with these modes. The number of trapped modes is shown to depend on the gross features of the sound channel, while the distribution of modal wave numbers depends to a greater degree on the details of the sound speed profile shape.

83-2060

The Low Wavenumber Wall Pressure Spectrum on a Flexible Surface

A.P. Dowling

Cambridge Univ. Engrg. Dept., Cambridge CB2 1PZ, UK, J. Sound Vib., 88 (1), pp 11-25 (May 8, 1983) 6 figs, 12 refs

Key Words: Turbulence, Fluid-induced excitation, Plates, Noise reduction

The Lighthill theory has been extended so that it may be used to determine the flow noise induced by a turbulent boundary layer over a flexible surface. The theory brings out explicitly the effects of the surface properties. The surface pressure spectrum has been investigated in detail for a bending plate, and the effects of surface dissipation and a coating layer have been determined. It is found that damping in the plate or some coating layers can have a beneficial effect and reduce certain spectral components of the flow noise. However coatings with a low sound speed are found to have an adverse effect on the flow noise.

83-2061

Finite Element Formulations for Acoustical Radiation

R.J. Astley and W. Eversman

Univ. of Missouri-Rolla, Rolla, MO 65401, J. Sound Vib., 88 (1), pp 47-64 (May 8, 1983) 10 figs, 15 refs

Key Words: Elastic waves, Sound waves, Finite element technique

Finite and infinite element techniques are applied to linear acoustical problems involving infinite anechoic boundaries. Theory is presented for a simple one-dimensional model based on Webster's horn equation. Results are then presented both for the one dimensional model and for two axisymmetric test cases. Comparisons with exact solutions indicate that both the infinite element and wave envelope schemes are effective in correctly predicting the near field. The wave envelope scheme is also shown to be capable of resolving the far field radiation pattern.

83-2062

Underwater Ambient Noise. Proceedings of a Conference Held at SACLANTCEN on 11-14 May 1982. Volume II. Unclassified Papers. Part 1

R.A. Wagstaff and O.Z. Bluy

SACLANT ASW Res. Centre, La Spezia, Italy, Rept. No. SACLANTCEN-CP-32-VOL-2-PT-1. 187 pp (June 15, 1982)
AD-A125 323

Key Words: Underwater sound, Noise measurement, Sound measurement

Contents: BACKGROUND – Role of propagation in ambient noise; MECHANISMS – Acoustic source characteristics of merchant ships; Flow-noise interference in measurements of infrasonic ambient noise; LOW-FREQUENCY PHENOMENA – Low-frequency seismic and hydroacoustic noise measurements in a fjord; Seismic and hydroacoustic sensing of infrasonic noise in coastal waters; MEASUREMENTS AND MEASUREMENT TECHNIQUES – Le programme Ulysse; Arctic ambient noise statistical measurement results and their implications to sonar performance improvements; Acoustic ambient noise in the Barents Sea; Depth dependence of directionality of ambient noise in the North Pacific: experimental data and equipment design; Ambient noise levels in the northeast Pacific ocean as measured by aircraft-dropped sonobuoys; PROCESSING TECHNIQUES – A real-time system for towed-array calibration and performance analysis, or how to get 50 dB sidelobes from a towed array; Notes on the interpretation of ambient noise statistics.

83-2063

Underwater Ambient Noise. Proceedings of a Conference Held at SACLANTCEN on 11-14 May 1982. Volume II. Unclassified Papers. Part 2

R.A. Wagstaff and O.Z. Bluy

SACLANT ASW Res. Ctr., La Spezia, Italy, Rept. No.

SACLANTCEN-CP-32-VOL-2-PT-2, 172 pp (June 15, 1982)
AD-A125 324

Key Words: Underwater sound, Noise measurement

Contents: PROCESSING TECHNIQUES – A method of estimating the influence of ship's noise on ambient noise measurements; Optimal detection and tracking of acoustical noise sources in a time-varying environment; Influence of background-noise spatial coherence on high-resolution passive method; Performance of three averaging methods for various distributions; Is power averaging the best estimator for undersea acoustic data; MODELING: DEVELOPMENT AND USE – A parametric examination of some properties of the low-frequency ambient-noise field; Detection models and target-information processing; The prediction of temporal statistics of directional ambient shipping noise; Site and frequency dependence of ambient noise in the north eastern Pacific Ocean; ACOUSTIC PROPAGATION EFFECTS – Site dependence of wind-dominated ambient noise in shallow water; Effects of topographic blockage and ocean boundaries on low-frequency noise fields; The seamount as a noise barrier.

83-2064
The Combustion Noise Source
W.C. Strahle
School of Aerospace Engrg., Georgia Inst. of Tech., Atlanta, GA 30332, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 379-388, 2 figs, 16 refs

Key Words: Combustion noise

Noise produced by turbulent combustion process may be a dominant noise source in such situations as stationary gas turbine powerplants or furnaces. The noise generated may be attenuated by dissipative shielding, but an understanding of noise source would enable to minimize the noise by combustor design. The paper is concerned solely with source behavior.

83-2065
Predicting and Controlling Noise from Large Turbulent Diffusion Flames
D. Shore
Flaregas Corp., 100 Airport Executive Park, Spring Valley, NY 10977, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 389-396, 21 refs

Key Words: Combustion noise

The aim of this paper is to review the various aspects of noise generation in combustion devices with large turbulent diffusion flames, to illustrate areas in which noise control measures may be found to be effective, and to offer a guide to prediction of noise output to be expected from various types of flame. The experience and empirical data used for illustrations are chiefly from process furnace burners and elevated flares.

83-2066
Noise Control in Combustion Systems
L.L. Faulkner and A.A. Putnam
Battelle's Columbus Labs., 505 King Ave., Columbus, OH 43201, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, 10 figs, 1 table, 21 refs

Key Words: Combustion noise, Noise reduction

Basic phenomena involved in two types of combustion noise: narrow band combustion-driven oscillations in which an acoustic feedback cycle is present and broadband combustion roar associated with turbulent flames, is outlined. A variety of control measures that have been implemented with various degrees of success are discussed in detail.

SHOCK EXCITATION

83-2067
Sources and Control of Noise from Impacting Type Machinery
L.L. Faulkner
Battelle's Columbus Labs., 505 King Ave., Columbus, OH 43201, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 415-424, 12 figs

Key Words: Machinery noise, Impact noise, Noise reduction

This article presents a general overview of the types of source mechanisms and some noise control methods for impact

problems in machinery. It is shown that specific noise reduction and prediction techniques such as vibration isolation and enclosure must be treated differently when impulsive sources are considered as compared to the usual steady state methods, specifically shock isolation and transmission loss.

83-2068

The Research of Dynamics of Striking Ice-Crusher

V. Veteris, B. Kučinskas, V. Ragulskienė, and V. Sabatauskienė
Kaunas Politechnic Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 4 (38), pp 145-158 (1981) 18 figs, 2 refs
(In Russian)

Key Words: Impact response, Tools

The results of an investigation of an impacting ice crusher are presented. Free and forced impact fluctuations are investigated and conditions for the presence of constant periodical forced impact fluctuations are determined. The loss of kinetic energy caused by collision in the tangential and normal directions is determined.

83-2069

Simulated Blast Testing of Advance Interceptor Materials

E.D. Esparza
Southwest Res. Inst., San Antonio, TX, Rept. No. AMMRC-TR-82-29, 43 pp (May 1982)
AD-A124 374

Key Words: Blast loads, Simulation

An experimental program was conducted to develop a simulation blast loading technique for testing advance interceptor materials. Kevlar/epoxy, carbon/epoxy, and hybrid frusta were tested with 50 and 80 psig reflected blast loads. The carbon frusta sustained the least amount of visible damage, while the hybrid frusta revealed the most damage from the simulated blast loads.

83-2070

Design Methodology for Structures with Large Seismic Overturning Moments

S.-L. Shein
Ph.D. Thesis, Case Western Reserve Univ., 399 pp (1982)
DA8306357

Key Words: Seismic design, Design techniques

Considerable interest currently exists concerning structures which tend to develop large overturning moments during seismic excitation. Several analytical and experimental studies have indicated that allowing transient uplift in such structures is often an attractive design alternative, in lieu of providing sufficient anchorage to resist the total conventionally computer overturning effect. Analytical tools exist, and are constantly being refined, which are capable of accurately evaluating the highly nonlinear uplift response of a given design to a given excitation. This study develops a series of response spectra for logically arriving at a preliminary design for such structures, based upon generalized ground motion parameters.

83-2071

Nonstationary Analysis and Simulation of Seismic Signals

B. Tiliouine
Ph.D. Thesis, Stanford Univ., 265 pp (1983)
DA8307231

Key Words: Seismic excitation, Simulation

A method for the simulation of artificial earthquakes is developed. Current procedures used in stochastic simulation of earthquake records are surveyed in some detail. A physical spectrum is presented and its significance discussed for the nonstationary characterization in intensity and spectral content of earthquake processes. Some important relationships between the physical spectrum and some destructiveness measures of earthquake ground motion are formulated. The procedure is oriented toward the use of a digital computer and is developed to model the temporal variation of the ground motion frequency content.

83-2072

Vibroseismic Excitation of Elastic Waves in a Semi-Infinite Solid

C. van Onselen
Afdeling Elektrotechniek, Technische Hogeschool,

Delft, The Netherlands, Rept. No. 1982-10, 138 pp (Aug 1982)
PB83-165365

Key Words: Seismic excitation

The elastodynamic field generated by a harmonically vibrating rigid rectangular base-plate on the traction-free surface of a semi-infinite homogeneous isotropic solid is investigated.

83-2073
Seismic Engineering Leaflets. Volume 1
Muto Inst. of Structural Mechanics, Tokyo, Japan, 228 pp (Feb 1982)
PB83-173088

Key Words: Seismic analysis, Seismic response

The document consists of a collection of leaflets concerning the seismic analysis of different types of structures.

VIBRATION EXCITATION

83-2074
Application of Wiener-Hermite Expansion to Nonstationary Random Vibration of a Duffing Oscillator
A. Jahedi and G. Ahmadi
Dept. of Mech. Engrg., Shiraz Univ., Shiraz, Iran, J. Appl. Mech., Trans. ASME, 50 (2), pp 436-442 (June 1983) 7 figs, 36 refs

Key Words: Random vibration, Duffing's oscillators

Nonstationary random vibration of a Duffing oscillator is considered. The method of Wiener-Hermite series expansion of an arbitrary random function is reviewed and applied to the analysis of the response of a Duffing oscillator. Deterministic integral equations for the Wiener-Hermite kernel functions are derived and discussed. For the special case of a shaped white-noise excitation, the system of integral equations are solved by an iterative scheme and the mean square responses of a Duffing oscillator for various values of nonlinearity strength and damping coefficient are calculated and the results are elaborated in several graphs.

83-2075
The Radially Flexible Pendulum Subjected to a High-Frequency Excitation
B.A. Schmidt
Central Michigan Univ., Mount Pleasant, MI 48859, J. Appl. Mech., Trans. ASME, 50 (2), pp 443-448 (June 1983) 2 figs, 15 refs

Key Words: Pendulums, Harmonic excitation, High frequency excitation

A high-frequency harmonic excitation is applied to a pendulum that is flexible in the radial direction. Approximate equilibrium positions are found when the excitation is in a general and fixed direction. An approximate stable motion is found when the direction of the excitation changes constantly and slowly. It is found that the excitation causes a reduction of the radius.

83-2076
Response of Two-Degree-of-Freedom Systems to Multifrequency Parametric Excitations
A.H. Nayfeh
Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 88 (1), pp 1-10 (May 8, 1983) 15 refs

Key Words: Two degree of freedom systems, Parametric excitation

The method of multiple scales is used to analyze the response of two-degree-of-freedom systems to multifrequency parametric excitations. The equations describing the modulation of the amplitudes with time are derived for the case of four simultaneous resonances: main resonances of the two modes, combination resonance of the difference type, and combination resonance of the summed type.

MECHANICAL PROPERTIES

DAMPING

83-2077
Digital Simulation of Friction Applied to a Simple Mass-Spring Damper System
D.T. Cuong and C.B.A. Young

B.S. Thesis, Dept. of Aeronautical Engrg., Bristol Univ., UK, Rept. No. BU-275, 61 pp (June 1982) N83-17234

Key Words: Friction, Sliding friction, Damping, Mass-spring systems, Digital simulation, Damping, Periodic excitation

In order to validate digital simulation of sliding friction in a mechanical system against a real system, friction was introduced to a mass-spring test rig. An accelerometer provided time response records of acceleration on an ultraviolet strip chart recorder. Comparison of equivalent experimental and simulated runs was based on the release from an initial displacement, and the sinusoidal excitation by displacement input. Good agreement is obtained for all cases, with the classical response shapes usually associated with friction being observed.

83-2078

Laboratory Test and Feasibility Study of Two Countermeasures to Subsynchronous Resonance

Y. Ichihara, T. Kotake, K. Watanabe, S. Takeda, K. Katsuki, H. Suzuki, and R. Fujiwara

Tokyo Electric Power Co., Inc., Tokyo, Japan, IEEE Trans., Power Apparatus Syst., PAS-102 (2), pp 300-311 (Feb 1983) 17 figs, 6 refs

Key Words: Damping, Vibration damping, Subsynchronous vibration

This paper presents two countermeasures to subsynchronous resonance. One is a dynamic resistor which is controlled by thyristor switches based on shaft torsional oscillations; the other, a new dynamic compensator.

83-2079

On the Amplitude Decay of Strongly Non-Linear Damped Oscillators

T.D. Burton

Dept. of Mech. Engrg., Washington State Univ., Pullman, WA 99164, J. Sound Vib., 87 (4), pp 535-541 (Apr 22, 1983) 4 figs, 15 refs

Key Words: Oscillators, Damped structures

The problem considered is that of the amplitude behavior of a strongly nonlinear damped oscillator. A simple approximation to the amplitude decay is obtained by first linearizing the static terms and then using the WKB approximation. Of particular interest is the influence of the nonlinearity on the amplitude decay. Several examples which illustrate this influence are provided.

83-2080

The Determination of Damping Behaviour of Viscoelastic Substrates from High Speed Rolling Friction Tests

V.G. Zankin

Ph.D. Thesis, Univ. of New South Wales, Australia (1982)

Key Words: Tires, Sliding friction, Elastomers, Damping coefficients

Improvements to frictional coupling between a lubricated sliding tire and a road surface can be found from an understanding of rubber friction. Under highly lubricated sliding conditions, rubber hysteresis or damping is considered to be the principal source of wet road friction. An experimental laboratory test program was undertaken to extend the range of prior published laboratory friction studies. A high speed rolling friction apparatus was developed to determine rubber damping characteristics up to rolling speeds of 73 kms/hr. at various loads and elevated temperatures. Rolling cylinders under approximately plane stress conditions were employed to permit conversion of rolling friction measurements to a corresponding damping factor using the mechano-lattice stress-strain analysis. The damping factor provides a quantitative measure of viscoelastic hysteresis and other energy dissipating properties.

ELASTICITY AND PLASTICITY

83-2081

Response of Cracks in Structural Materials to Short Pulse Loads

H. Homma, D.A. Shockey, and Y. Murayama

Dept. of Metallurgy and Fracture Mechanics, Poulter Lab., SRI International, Menlo Park, CA 94025, J. Mech. Phys. Solids, 31 (3), pp 261-279 (1983) 9 figs, 1 table, 21 refs

Key Words: Crack propagation, Pulse excitation, Aluminum

Cracks in single-edge-notched strip specimens of 4340 steel, 1018 steel, and 6061-T651 aluminum were loaded by tensile pulses of various amplitudes and durations to determine critical stresses for crack instability. The results were not

well described by static fracture mechanics, but were in accord with behavior inferred from considerations of crack-tip stress intensity histories.

83-2082

Estimating Fatigue Crack Initiation and Propagation Life of Cast Steels under Variable Loading History

Sung-Gun Lee

Ph.D. Thesis, Univ. of Iowa, 246 pp (1982)

DA8310072

Key Words: Crack propagation, Steel

Fatigue crack initiation life at a notch and crack growth life of cast steels, which show very low fatigue notch sensitivity, was investigated under variable loading. A new method to obtain the fatigue notch factor and the characteristic length was developed using the elastic stress distribution under the fatigue limit of a notched specimen. The characteristic length was obtained at the point where the stress is the same as the fatigue limit of unnotched specimen. Assuming the characteristic length is a material constant, the fatigue notch factor for a keyhole specimen was obtained using the elastic stress distribution. For crack initiation life calculations, both modified Neuber's rule and elastic-plastic FEM analysis were used to obtain the stress and strain of each cycle counted by the rainflow counting method.

83-2083

Characterization of Dynamic Viscoelastic Properties of Elastomers Using Digital Spectral Analysis

S.N. Ganeriwala

Ph.D. Thesis, Univ. of Texas at Austin, 258 pp (1982)

DA8309147

Key Words: Elastomers, Viscoelastic properties, Spectrum analysis

The linear dynamic behavior of an elastomer can be predicted if certain material properties, such as the complex modulii, are known over the appropriate range of frequencies. The properties are usually measured by subjecting a specimen to single-frequency sinusoidal excitation and determining the response. The tests are then repeated until the complete frequency range of interest is covered. This dissertation describes how digital spectral analysis techniques can be used to measure these same properties using random white noise excitation. Thus one simple test produces data covering a range of frequencies, resulting in time savings and other benefits. A theoretical description of the method is presented.

83-2084

The Dynamic Stress Intensity Factor Due to Arbitrary Screw Dislocation Motion

L.M. Brock

Univ. of Kentucky, Lexington, KY 40506, J. Appl. Mech., Trans. ASME, 50 (2), pp 383-389 (June 1983) 5 figs, 13 refs

Key Words: Crack propagation

The dynamic stress intensity factor for a stationary semi-infinite crack due to the motion of a screw dislocation is obtained analytically. The dislocation position, orientation, and speed are largely arbitrary. However, a dislocation traveling toward the crack surface is assumed to arrest upon arrival. It is found that discontinuities in speed and a non-smooth path may cause discontinuities in the intensity factor and that dislocation arrest at any point causes the intensity factor to instantaneously assume a static value.

83-2085

Transient Response of an Elastic Medium to Torsional Loads on a Cylindrical Cavity

R. Parnes and L. Banks-Sills

Tel-Aviv Univ., Ramat-Aviv, Tel-Aviv, Israel 69978, J. Appl. Mech., Trans. ASME, 50 (2), pp 397-404 (June 1983) 11 figs, 16 refs

Key Words: Elastic media, Transient response, Torsional excitation

The transient response of an elastic medium to torsional line loads acting as a step function in time on the surface of an infinite cylindrical bore is obtained. The solution is seen to be composed of a superposition of space-harmonic applied tractions. Integral representations of the resulting displacement and stress fields are derived and numerical results are presented.

83-2086

How 'Mixed' is Dynamic Mixed-Mode Crack Propagation? -- A Dynamic Photoelastic Study

H.P. Rossmanith

Inst. of Mechanics, Technical Univ. Vienna, Karlsplatz 13, A-1040 Vienna, Austria, J. Mech. Phys. Solids, 31 (3), pp 251-260 (1983) 6 figs, 7 refs

Key Words: Crack propagation, Photoelastic analysis

Dynamic photoelastic fringe recordings associated with rapid curved crack propagation, crack division and the interaction

between moving cracks and elastic waves show global dynamic mixed-mode crack-tip fringe patterns. When analyzed by means of K-determination procedures an apparent dynamic mixed-mode ratio K_2/K_1 may be defined which turns out to be a function of the particular selection of measurement data points. This paper compares experimentally recorded fringe data with numerical results in an attempt to resolve the dynamic photoelastic mixed-mode crack problem.

WAVE PROPAGATION

(Also see Nos. 2059, 2061)

83-2087

Theoretical Investigation of Sound Damper, Based on Scattering of Sound by Sound

L. Bastytė and R. Soloviov

Kaunas Politechnic Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 4 (38), pp 137-143 (1981) 3 figs, 8 refs

(In Russian)

Key Words: Sound waves, Wave scattering

The sound damper is investigated theoretically, based on the principle of scattering of sound by sound. Expression for the calculation of the effect of sound damping is obtained.

83-2088

On the Scattering of Sound by a Vortex Ring

M.S. Howe

Faculty of Mathematical Studies, Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 87 (4), pp 567-571 (Apr 22, 1983) 2 figs, 6 refs

Key Words: Acoustic scattering

An analytical treatment is given of the scattering of sound by a circular vortex ring translating at low Mach number in an unbounded stationary medium. The theoretical results complement a recent numerical investigation of this problem.

83-2089

Acoustical Measurement of Solid State Non-Linearity: Application to $CsCdF_3$ and $KZnF_3$

M.A. Breazeale, J. Philip, A. Zarembowitch, M. Fischer, and Y. Gesland

Dept. of Physics, Univ. of Tennessee, Knoxville, TN 37996-1200, J. Sound Vib., 88 (1), pp 133-140 (May 8, 1983) 5 tables, 33 refs

Key Words: Wave propagation, Periodic excitation, Elastic waves, Sound waves

Combination of the results of two sets of measurements on the same crystalline samples of $CsCdF_3$ and $KZnF_3$ has made possible the evaluation of the third-order elastic (TOE) constants of these two fluoroperovskites. In the first technique the hydrostatic pressure dependence of the velocity of ultrasonic waves of different propagation and polarization directions has been measured to determine three linear combinations of TOE constants. In the second technique the fundamental and the second harmonic amplitudes of an initially sinusoidal longitudinal ultrasonic wave of finite amplitude propagating along the principal directions have been measured to determine three other linear combinations.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

(Also see No. 2100)

83-2090

How to Select a Low-Priced Sound Level Meter

G.M. Hynes

Fireman's Fund Ins. Co., Detroit, MI, S/V, Sound Vib., 17 (5), pp 20-22 (May 1983) 1 fig, 1 table

Key Words: Sound level meters

Selecting a sound level meter can be a confusing task. Many individuals on limited budgets wish to purchase a simple, basic sound level measuring instrument. Such meters are discussed in detail. A comparison table of selected instruments lists their various features and costs.

83-2091

Computerized Measurement and Tracking of Acoustical Resonances

D.V. Conte

Naval Postgraduate School, Monterey, CA, 38 pp (Dec 1982)
AD-A125 286

Key Words: Measuring instruments, Acoustic resonance, Computer-aided techniques

A system is described which incorporated a desk-top computer to control a frequency synthesizer and read the output of a lock-in analyzer to measure, display and record the resonant frequencies, amplitudes, and quality factors of several modes of an acoustical resonator. The system is capable of locating, measuring, and tracking the resonant modes, as parameters which affect sound speed and attenuation are varied.

83-2092

Deconvolution of the Signals Propagated through Machine Structure

A. Ordubadi

Bolt Beranek and Newman Inc., 10 Moulton St., Cambridge, MA 02238, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 333-338, 1 ref

Key Words: Transfer functions, Deconvolution technique, Signal processing techniques

The properties of the TF of propagation in a dispersive medium via a few paths were studied. The feasibility of using these properties for deconvolution of the received signals propagated through this type of medium is determined.

83-2093

Measurement of Vibrations of Moving Objects Using Laser-Doppler-Vibrometry (Vibrationsmaetning pa Roeriga Foeremal med Hjaelp av Laser-Doppler-Vibrometri (LDV)

N.-A. Nilsson

IFM Akustikbyran A.B., Stockholm, Sweden, 19 pp (1982)
PB83-159640
(In Swedish)

Key Words: Vibration meters, Lasers, Doppler effect

The text of a lecture on the laser-doppler vibrometer, with emphasis on practical uses to which the device can be put is presented. A bibliography, diagrams and a photograph of the device are included. The laser-doppler vibrometer is described, in lay terms, as something like a doppler radar, but with light waves instead of radar waves. The functioning of the device is described, giving the applicable equation and a schematic diagram. Commercial sources of the laser-doppler vibrometer in Sweden and Denmark are given and prices are cited.

83-2094

An Acoustic Intensity Spacial Sampling Technique for Measuring the Sound Power of Industrial Equipment In-Situ

H.A. Wolf

Exxon Res. and Engrg. Co., Florham Park, NJ 07932, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 343-348, 5 figs, 5 refs

Key Words: Acoustic intensity method, Two microphone technique, Cross spectral method, Measurement techniques, Noise measurement, Sound power levels, Industrial facilities

A two-microphone (cross-spectral) acoustic intensity technique for in-situ measurement of sound power on large industrial equipment is described. The technique provides measuring locations much closer to the source by evaluating only the in-phase acoustic pressure and velocity, thus minimizing the difficulties from background noise incurred using single-microphone near field SPL measurements.

83-2095

A General Theoretical Formulation for Acoustic Intensity Method Using Two Microphones

G.P. Mathur

Structural Dynamics Div., Beech Aircraft Corp., Wichita, KS 67201, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 349-354, 7 refs

Key Words: Acoustic intensity method, Two microphone technique, Cross spectral method, Stochastic processes, Measurement techniques, Noise measurement, Sound power levels

A general theory for the two-microphone acoustic intensity method is formulated, using linear mean square estimation as applied to stochastic processes and some concepts of multidimensional stochastic processes.

83-2096

Determining Source Signatures from Vibration Measurements and Transfer Functions

R.E. Powell

Cambridge Collaborative, Inc., 225 Third St., P.O. Box 74, Cambridge, MA 02142, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, 8 figs, 9 refs

Key Words: Signal processing techniques, Filters (frequency)

This paper is concerned primarily with the use of linear multichannel filtering to produce estimates of input forces from vibration data when the frequency response functions between the inputs and the vibration measurement locations are known.

83-2097

A Vector Space Approach to Time-Variant Energy Spectral Analysis

J.E. Roach

Ph.D. Thesis, Syracuse Univ., 247 pp (1982)
DA8310468

Key Words: Spectrum analysis

The main contribution of this research is to establish a general vector space approach to the representation of signal energy in time and frequency. In achieving this end, a theoretical justification for the piecewise Fourier transform approach is provided. Furthermore, a general class of windowed Fourier series expansions is developed which forms a solid basis for the application of weighting windows to energy spectral analysis. Rules-of-thumb are developed for application of the proposed vector space approach to realistic signal observation. A number of examples are given to compare the spectral characteristics of windowed Fourier series expansions.

83-2098

An Iterative Algorithm for Solving Inverse Problems in Structural Dynamics

Y.M. Chen and Yi Lin

Dept. of Appl. Mathematics and Statistics, State Univ. of New York at Stony Brook, Stony Brook, NY, Intl. J. Numer. Methods Engrg., 19 (6), pp 825-829 (June 1983) 1 fig, 11 refs

Key Words: Pulse-spectrum techniques, Parameter identification techniques, Design techniques, Time domain method

The pulse-spectrum technique (PST), an iterative numerical algorithm, is presented and extended to solve the inverse problems arising from the dynamic structural identification and structural design problems. A simple one-dimensional shear beam model is used to demonstrate the applicability of PST. Numerical simulations are carried out to test the feasibility and to study the general characteristics of this technique without the real measurement and design data.

DYNAMIC TESTS

(Also see No. 1965)

83-2099

Dynamic Testing of Waveform Recorders

B.E. Peetz

Hewlett-Packard Co., Santa Clara, CA 95050, IEEE Trans., Instrum. Meas., IM-32 (1), pp 12-17 (Mar 1983) 3 figs, 12 refs

Key Words: Dynamic tests

Four waveform recorder tests are presented that characterize dynamic performance using sine-wave sources. Each test illuminates different aspects of dynamic performance, and in some cases indicate the specific errors limiting performance. Pitfalls in using the tests are also examined.

83-2100

Measuring Properties of Fast Digitizers Employed for Recording HV Impulses

R.A. Malewski, T.R. McComb, and M.M.C. Collins

Institut de Recherche d'Hydro-Quebec, Varennes, Quebec, Canada J01 2PO, IEEE Trans., Instrum. Meas., IM-32 (1), pp 17-22 (Mar 1983) 10 figs, 1 table, 6 refs

Key Words: Measuring instruments, Digital techniques, Impulse testing

Requirements on measuring accuracy of high-voltage (HV) impulses employed for testing of self-restoring and non-self-restoring insulation are reviewed in order to select a suitable digitizer for the impulse recording. This paper analyzes the equivalent bits characteristic which is frequently employed as a criterion of the digitizer dynamic performance, and an additional test of the digitization error distribution is pro-

posed. Such a test results in another characteristic of the equivalent bits, which is based on the maximum (rather than the rms) error and which reflects the actual deformation of the recorded impulse form.

83-2101
Mechanical Test Stand for the Measurement of the Vibration Levels of Chain Saws During Cutting Operations

D.D. Reynolds and F.L. Wilson

Joiner-Pelton-Rose, Inc., 10110 Monroe Dr., Dallas, TX 75229, J. Sound Vib., 88 (1), pp 65-84 (May 8, 1983) 13 figs, 7 tables, 3 refs

Key Words: Test facilities, Vibration measurement, Saws

A mechanical test stand and corresponding test procedures for measuring the vibration levels of chain saws during cutting operations has been developed. The stand includes mechanical coupling devices that approximate the dynamic response characteristics of the hand to clamp the top and rear saw handles. The stand is designed so that saws of all types and shapes can be tested. Results of hand-held and machine-held vibration tests on chain saws are discussed.

83-2102
NDE -- Nondestructive Examination

S.D. Strauss, Sr. Editor

Power, 127 (6), pp S-1 - S-16 (June 1983) 44 figs, 6 refs

Key Words: Nondestructive tests, Ultrasonic techniques, Acoustic emission

Leading nondestructive techniques used to ensure component integrity during powerplant service are reviewed, among them eddy-current, ultrasonic and acoustic emission.

SCALING AND MODELING

83-2103
Scale Modeling Flow-Induced Vibrations of Reactor Components

T.M. Mulcahy

Argonne Natl. Lab., Argonne, IL, Rept. No. ANL-CT-8215, 40 pp (June 1982)
DE82021142

Key Words: Nuclear reactor components, Fluid-induced excitation, Scaling

Similitude relationships currently employed in the design of flow-induced vibration scale-model tests of nuclear reactor components are reviewed. Emphasis is given to understanding the origins of the similitude parameters as a basis for discussion of the inevitable distortions which occur in design verification testing of entire reactor systems and in feature testing of individual component designs for the existence of detrimental flow-induced vibration mechanisms. Distortions of similitude parameters made in current test practice are enumerated and selected example tests are described.

DIAGNOSTICS

83-2104
Vibrothermography: Investigation and Development of a New Nondestructive Evaluation Technique

E.G. Henneke, II, K.L. Reifsnider, W.W. Stinchcomb, and S.S. Russell

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, Rept. No. ARO-16202.9-MS, 15 pp (Jan 1983)
AD-A125 141

Key Words: Diagnostic techniques, Nondestructive tests

A summary is presented of the major findings of a program the objective of which was to investigate the phenomenon of preferential heat generation around damaged regions in materials subjected to mechanical vibrations and to develop an understanding of the mechanisms involved in this process. Vibrothermography is a nondestructive inspection technique based upon the utilization of this phenomenon. It has been found that this technique has much potential for inspecting composite materials. A significant amount of knowledge has been gained concerning the nature of the heat generation process and the relation of the frequency dependence of the heat patterns to the mechanical excitations.

83-2105
Reduction of Combustion-Driven Acoustic Oscillations in a High-Pressure Steam Generation Boiler

J. Hersman, L.L. Faulkner, M. Hock, and C. Rodman

Procter & Gamble Co., Cincinnati, OH, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 407-412, 2 figs, 2 refs

Key Words: Boilers, Diagnostic techniques, Case histories, Combustion noise

An experimental and analytical approach for solving the problem of severe vibration of a high-pressure boiler, shortly after it is placed in operation, is described.

BALANCING

83-2106

Dynamic Balance Improvement Program

M.F. Butner

Rocketdyne Div., Rockwell International, Canoga Park, CA, Rept. No. NASA-CR-170711, 315 pp (1983)

N83-17881

Key Words: Dynamic balancing, Space shuttles, Engines

The reduction of residual unbalance in the space shuttle main engine (SSME) high pressure turbopump rotors is addressed. Elastic rotor response to unbalance and balancing requirements, multiplane and in house balancing, and balance related rotor design considerations are assessed. Recommendations are made for near term improvement of the SSME balancing and for future study and development efforts.

83-2107

State-of-the-Art Technique for Power System Stabilizer Tuning

R.G. Farmer and B.L. Agrawal

Arizona Public Service Co., P.O. Box 21666, Phoenix, AZ 85036, IEEE Trans., Power Apparatus Syst., PAS-102 (3), pp 699-709 (Mar 1983) 16 figs, 1 table, 16 refs

Key Words: Tuning, Fast Fourier transform, Digital techniques

Power system stabilizers (PSS) have broad application throughout the world. PSS application requires careful tuning which is usually accomplished in the field with the generator and power system in an abnormal condition. Recently developed equipment which combines fast Fourier transform capability with digital computer technique provides a means of PSS tuning which is faster and more accurate than was previously obtainable. This paper describes a PSS tuning test conducted using the new technique.

MONITORING

83-2108

Incipient Fault Identification through Neutral RF Monitoring of Large Rotating Machines

J.E. Timperley

American Electric Power Service Corp., Canton, OH 44701, IEEE Trans., Power Apparatus Syst., PAS-102 (3), pp 693-698 (Mar 1983) 15 figs, 2 refs

Key Words: Monitoring techniques, Incipient failure detection, Rotating machinery

Electromagnetic interference, or EMI, monitoring at an operating machine's neutral can detect many types of stator deterioration, as well as various design defects. Accurate, wide-band spectrum analysis may indicate a problem's location, its severity and its rate of change. This method can be sensitive enough to detect potential faults long before an in-service failure occurs. The salient results of numerous tests conducted during 1980 and 1981 are presented.

83-2109

Noise Reduced Digital Device Detecting Angular Speed Deviation and Acceleration for Transient Control Augmentation

R. Ueda, T. Sonoda, S. Takata, and T. Irisa

Kyushu Inst. of Tech., Kitakyushu, Japan, IEEE Trans., Power Apparatus Syst., PAS-102 (1), pp 180-185 (Jan 1983) 8 figs, 8 refs

Key Words: Monitoring techniques, Control equipment, Shafts

Stabilization strategy to keep the constant shaft speed of a machine in the transient state requires fast and accurate detection of a minimum two quantities, speed deviation and acceleration of the shaft. Random noise caused by shaft vibration, frequency fluctuation of electrical system, etc. must be reduced as much as possible, and a detecting device is also required to be compatible with the control system

designed for constant rotor speed. This paper presents a new digital detecting device sufficiently satisfying these requirements.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

83-2110

The Lumped Parameter Method for Elastic Impact Problems

Yong-Chun Lee

Ph.D. Thesis, Purdue Univ., 157 pp (1982)
DA8310837

Key Words: Lumped parameter method, Impact response

A fundamental study of the mechanical impact between two elastic bodies is undertaken. The objective of the study is to develop an analytical method to predict the impact force for subsequent application to vibration and noise problems. The basis of the method evolved consists of replacing the continuous elastic bodies by a finite assembly of spring-mass-damper elements which collectively duplicate the contact point mobilities of the original bodies. The contact interface is provided by a Hertzian contact law model; and the mobilities by either modal expansion methods or by experiment. Several classical impact problems involving simple beams and plates are solved to illustrate the method and to assess its accuracy. Two mechanical systems consisting of a free rigid mass transversely impacting a free-free beam and a freely suspended plate are given as illustration of complex body shapes where the contact mobilities were obtained by measurement.

83-2111

New Algorithms for Transient Finite Element Analysis

N. Patamapongs

Ph.D. Thesis, Drexel Univ., 165 pp (1983)
DA8308272

Key Words: Finite element technique, Transient response

The possibility of constructing finite element algorithms for nonlinear time-dependent problems which are stable relative to the finite amplitude instabilities without resorting to the injection of artificial damping or the imposition of additional constraints is investigated. A method is suggested in which the nonlinear terms are temporally approximated in such a way that the resulting algorithm describes a discrete conservation law. Formulas are developed for use in conjunction with the central difference operator which allow a systematic construction of such implicitly-conserving schemes for elastodynamic problems involving arbitrary degrees of nonlinearities.

83-2112

Equivalent Linearization for Continuous Dynamical Systems

W.D. Iwan and C.M. Krousgrill, Jr.

California Inst. of Tech., Pasadena, CA, J. Appl. Mech., Trans. ASME, 50 (2), pp 415-420 (June 1983) 3 figs, 6 refs

Key Words: Equivalent linearization method

An approximate method is presented for determining the dynamical response of certain continuous nonlinear systems. In the proposed method, the system equation is linearized in the time domain prior to generation of a solution in the spatial domain. The approach is particularly suited to problems with complex boundary conditions which make selection of realistic global, spatial, domain comparison functions difficult. The approach is ideally suited to problems where discretization using finite elements is appropriate. The transverse response of a nonlinear rectangular plate is examined by way of the application of the proposed method.

83-2113

Asymptotical Evaluation of the Natural Frequency of Machinery by Means of Dynamic Models

V. Veytz, N. Vitalyeva, and E. Kochura

VTUZ pri proizvodstvennom obedinenii "Leningradskorii metallicheskii zavod," USSR, Vibrotechnika, 4 (34), pp 33-39 (1981) 2 figs, 12 refs
(In Russian)

Key Words: Natural frequencies, Machinery

Natural frequencies of multidimensional linearized dynamic models of machinery with variable elastic-inertial properties are investigated by means of perturbation theory.

83-2114

Dynamics of Two-Dimensional Vibro-Percussive System, III

V. Veteris, B. Kučinskas, V. Ragulskienė, and V. Sabatauskienė

Kaunas Politechnic Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 3 (33), pp 7-13 (1981) 12 figs, 4 refs

(In Russian)

Key Words: Vibration analysis

Dynamic properties of a two-dimensional vibro-impact system are investigated. Localization of kinetic energy loss in the normal direction and its dependence on the discriminate parameters is shown. The kinetic energy loss yields multi-functions of multivariable parameter systems. The ripple of energy frequency response is derived.

83-2115

A Method of Independent Cycles of Direct Transformation of a Mechanical System into a Signal Flow Graph

J. Voinarovski and E. Svider

Vibrotechnika, 3 (33), pp 87-94 (1981) 7 figs, 9 refs

(In Russian)

Key Words: Mathematical models

The paper deals with an algorithm for the construction of signal flow graphs of complex mechanical systems. The suggested conventions with signs and the division of the signals of the through variables $_2s(p)$ and across-variables $_1s(p)$ makes it possible to model directly complex mechanical systems by means of signal flow graphs. The transformation of the system into a signal flow graph is illustrated.

83-2116

Optimization of Vibration Motion Transducers

G. Kulvietis, G. Markauskaite, and K. Ragulskis

Kaunas Politechnical Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 4 (38), pp 53-61 (1981) 3 figs, 2 tables, 6 refs

(In Russian)

Key Words: Transducers, Optimization

The finite element technique is used for the dynamic analysis of two vibration motion transducers. The optimization of parameters of such transducers is carried out and an analysis of the obtained results is presented.

83-2117

Multi-Level Substructuring of Large Structural Systems for the Eigenproblem

R. Rajatabhothi

Ph.D. Thesis, The University of Texas at Austin, 405 pp (1982)

DA8309190

Key Words: Eigenvalue problems, Substructuring methods, Modal synthesis, Quadratic reduction

Computational aspects of two substructure methods for solving the eigenvalue problem of a large structural system are presented. The methods, modal synthesis and quadratic reduction, provide more accurate eigensolutions than the Guyan reduction technique through application of corrective displacements to the substructure system generated from the large system. In the modal synthesis method, the corrective displacements are applied in the form of modal displacements that represent the interior behavior of the component substructures. The corrective displacements in the quadratic reduction technique also represent the interior behavior but involve no transformation from physical to modal coordinates.

83-2118

Lanczos Versus Subspace Iteration for Solution of Eigenvalue Problems

B. Nour-Omid, B.N. Parlett, and R.L. Taylor

Univ. of California, Berkeley, CA, Intl. J. Numer. Methods Engrg., 19 (6), pp 859-871 (June 1983) 9 figs, 7 refs

Key Words: Eigenvalue problems, Lanczos method, Subspace method

Solution of the eigenproblem in structural analysis using a recent version of the Lanczos method and the subspace method is considered. The two methods are applied to examples and it is concluded that the Lanczos method has definite advantages.

83-2119

Analysis of Non-Linear Autonomous Conservative Oscillators by a Time Transformation Method

T.D. Burton and M.N. Hamdan

Dept. of Mech. Engrg., Washington State Univ., Pullman, WA 99164-2920, J. Sound Vib., 87 (4), pp 543-554 (Apr 22, 1983) 1 fig, 18 refs

Key Words: Free vibration, Oscillators

The problem considered is that of the free vibration of the class of strongly nonlinear oscillators $\ddot{u} + mu + \alpha f(u) = 0$, where m = 1, 0 or −1, f(u) is a nonlinear function of the displacement u(t), and α is not small. Through a continuous stretching of the time t a new time T is found in whose domain the response is simple harmonic. This time transformation method allows the response u(t) and period τ to be calculated to any desired degree of accuracy; however, the primary objective is to develop reasonably simple, accurate approximations for the oscillators considered.

83-2120

Toward an Extremum Characterization of Kinetic Stability

J.G. Papastavridis

School of Engrg. Science and Mechanics, Georgia Inst. of Tech., Atlanta, GA 30332, J. Sound Vib., 87 (4), pp 573-587 (Apr 22, 1983) 2 figs, 29 refs

Key Words: Stability

In this paper the Hamiltonian action-based stability ideas of Routh are combined with Trefftz's variational formulation of the adjacent configuration method of static buckling into a comprehensive time-integral-of-energy-based extremum criterion of kinetic stability. Specifically, if the action functional along a fundamental path is a minimum for an arbitrarily long time interval of integration then the path is unstable, whereas if it ceases to do so at some point, then the path is stable up to that point; this latter leads to a direct method for approximate stability limit calculations. Some relevant analytical tools are also discussed, and finally applications of the criteria to the stability of equilibrium, and that of the steady state of Duffing's (cubic and harmonically-forced) oscillator are presented.

83-2121

Dynamical Behaviour of an Oscillator Sustained by an Intermittent Mechanism

F. Badrakhan

College of Engrg. and Petroleum, Kuwait Univ., Kuwait, J. Sound Vib., 88 (1), pp 27-36 (May 8, 1983) 4 figs, 10 refs

Key Words: Oscillators, Harmonic excitation, Random excitation, Natural frequencies

A new method for studying the dynamical behavior of an oscillator sustained by an intermittent mechanism is presented. Graham escapement is considered as a typical model for such a mechanism. A new form given to the equation of motion permits the study of the natural frequency of the system, the establishment of a first integral in the case of a free motion, and the analysis of effects of external harmonic or random perturbations.

NONLINEAR ANALYSIS

83-2122

Analytical and Numerical Treatment of Random Vibrations of Nonlinear Systems (Zur analytischen und numerischen Behandlung der Zufallsschwingungen nichtlinearer Systeme)

B. Miao

Institut f. Mechanik, Technische Hochschule Darmstadt, Germany, Fortschritt-Berichte VDI-Zt., Reihe 11, No. 51 (1982) 112 pp, 39 figs, 6 tables. Summarized in VDI-Z, 125 (3), p 60 (Feb 1983). Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Düsseldorf 1, Germany. Price 72.00 DM

(In German)

Key Words: Nonlinear systems, Random vibration, Monte Carlo method, Markov Vector method

The aim of this study was to develop and test methods for investigation of nonlinear random vibration, particularly the determination of autocorrelation function and the spectral density of steady state response. The limitations of the Markov Vector method are discussed in detail and the applicability of the Monte Carlo method is illustrated in the solution of various problems, such as in systems with one or several degrees of freedom, excitation caused by white noise as well as by non-white noise, and systems with various nonlinearities. In addition, random vibrations caused by continuous, as well as discrete excitation, are investigated.

NUMERICAL METHODS

83-2123

Numerical Dynamic Analysis of Structures by the Finite Dynamic Element Method

K.K. Gupta

Jet Propulsion Lab., Pasadena, CA, Rept. No. AFO-SR-TR-82-1095, 68 pp (Aug 15, 1982)
AD-A125 213

Key Words: Dynamic structural analysis, Numerical analysis

This report describes progress made in research during the final year of a five-year study of numerical dynamical analysis of structures. The proposed work effort in the final year's work included the following tasks: development of a higher order rectangular plane stress/strain finite element, development of a solid hexahedron finite dynamic element, and further refinement of the associated generalized eigenproblem solution routine.

OPTIMIZATION TECHNIQUES

(Also see Nos. 2116, 2134)

83-2124

Optimization of the Dynamic Response of Hydraulic Equipment by Means of Digital Computer (Digitalrechner optimiert dynamisches Verhalten hydraulischer Geräte)

H.L. Zimmermann

Maschinenmarkt, 89 (37), pp 799-802 (May 10, 1983) 11 figs, 3 refs
(In German)

Key Words: Computer programs, Hydraulic equipment, Design techniques

A universal digital computer program is described which already in the design stage identifies structural components affecting the dynamic response of the system. The program is written in Fortran IV and can be run on a small computer with a 64 KB memory. As input the schematic diagram of the hydraulic circuit is used with codes identifying the components. From this input the computer develops differential equations, which simulate the dynamic behavior of the circuit and presents graphically subsequent transient response of the system to certain input signals.

83-2125

Computational Methods for Static and Dynamic Systems and Engineering Applications

A. Miele

Rice Univ., Houston, TX, Rept. No. NSF/ECS-82007, 31 pp (1982)
PB83-176404

Key Words: Optimization, Control equipment

Progress in research on analytical and numerical methods for optimal control problems is reported. Topics under study include: supplementary optimality properties of gradient-restoration algorithms; conjugate gradient-restoration algorithms for optimal control problems with nondifferential constraints and general boundary conditions; Chebyshev problems of optimal control; linear, two-point boundary-value problems; and nonlinear, two-point boundary-value problems involving differential constraints, nondifferential constraints, and general boundary conditions.

COMPUTER PROGRAMS

(Also see No. 2124)

83-2126

ADAM: An Axisymmetric Duct Aeroacoustic Modeling System

A.L. Abrahamson

Comtek, Grafton, VA, Rept. No. NASA-CR-3668, 91 pp (Jan 1983)
N83-18406

Key Words: Computer programs, Ducts, Aircraft engines, Sound propagation, Sound attenuation, Noise reduction

An interconnected system of computer programs for analyzing the propagation and attenuation of sound in aero-engine ducts containing realistic compressible subsonic mean flows, ADAM was developed primarily for research directed towards the reduction of noise emitted from turbofan aircraft engines. The two basic components are a streamtube curvature program for determination of the mean flow, and a finite element code for solution of the acoustic propagation problem.

83-2127

Coal-Fired Propulsion System Dynamics. Volume II. Program Documentation and User's Guide

T.L. Greenlee and J.L. Pearsons

Quincy Ship Building Div., General Dynamics Corp.,

Quincy, MA, Rept. No. MA-RD-920-82063-B, 411 pp (Dec 1982)
PB83-163188

Key Words: Ships, Propulsion systems, Computer programs

This volume describes the use and internal details of a FORTRAN computer program that has been written for simulating the dynamic (transient) behavior of a dual-fired (coal or oil) ship propulsion system. The FORTRAN program implements and solves a system of coupled, nonlinear, first-order, ordinary differential equations that represent all major components of the ship propulsion system (feedwater pumps, boilers, headers, turbines, turbine/gears propeller shaft, and hull). These equations also represent all major control loops. The program incorporates a numerical linearization subroutine that can be used to generate the steady-state conditions for any operating point.

83-2128
Computer Program to Predict Noise of General Aviation Aircraft: User's Guide
J.A. Mitchell, C.K. Barton, L.S. Kisner, and C.A. Lyon
Garrett Turbine Engine Co., Phoenix, AZ, Rept. No. NASA-CR-168050, 281 pp (Sept 1982)
N83-17242

Key Words: Computer programs, Aircraft, Noise prediction

Program NOISE predicts General Aviation Aircraft farfield noise levels at FAA FAR Part 36 certification conditions. It will also predict near-field and cabin noise levels for turboprop aircraft and static engine component far-field noise levels.

GENERAL TOPICS

CRITERIA, STANDARDS, AND SPECIFICATIONS

83-2129
ARI Sound Rating and Certification of Residential Outdoor Air Conditioning Units
R.G. Harold
The Trane Co., 3600 Pammel Creek Rd., LaCrosse, WI 54601, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, pp 249-258, 3 figs, 1 table, 20 refs

Key Words: Standards and codes, Air conditioning equipment, Sound power levels, Rating

The ARI certification program and sound standards combine to produce a number of benefits for the users of residential air conditioners. This program has been upgraded to use a new sound descriptor, with tone corrected, A-weighted sound power expressed in bels. Certified ratings are published twice a year. An application standard guides the user in converting the sound rating into A-weighted sound pressure at a particular evaluation point.

83-2130
Published Results of the ARI Certified Sound Rating Program
A. Potter
Torin Corp., Kennedy Dr., Torrington, CT 06790, NOISE-CON 83, Quieting the Noise Source, Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983, 4 figs, 2 tables, 2 refs

Key Words: Standards and codes, Air conditioning equipment, Sound power levels, Rating

The Air-Conditioning and Refrigeration Institute (ARI) has completed over a dozen years of publishing certified sound ratings for outdoor unitary equipment. The first ARI directory to include sound rating numbers was published in January, 1971; up-dated editions have appeared regularly since then. This program covers the air-cooled outdoor portions of factory-made mechanical air-conditioning equipment or heat pumps rated in cooling capacity at less than 135,000 British thermal units per hour. The sound rating is based on test data taken while the outdoor equipment is operating with its rated electrical input and with its rated thermal load applied.

BIBLIOGRAPHIES

(Also see Nos. 2040, 2041)

83-2131
NOISE-CON 83, Quieting the Noise Source

Proc. of Natl. Conf. on Noise Control Engrg., Massachusetts Inst. Tech., Cambridge, MA, Mar 21-23, 1983

Key Words: Noise reduction, Proceedings

The conference focuses on diagnosing and understanding the generation of noise, predicting it, and controlling it at its origin. Three aspects of source noise control appear throughout this volume: basic theory, design and problem solving. Individual papers are abstracted in the appropriate sections of this issue.

USEFUL APPLICATIONS

83-2132

The Development and Analysis of Vibromotors with a Free Rotor. Part 1. Development of New Vibromotor Designs

V. Ragulskiėnė and L.A. Štacas

Kaunas Politechnical Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 4 (38), pp 163-169 (1981) 3 figs, 3 refs

(In Russian)

Key Words: Motors

Vibromotors with a free rotor are reviewed and classified and their areas of application are described. New designs are presented.

83-2133

The Development and Analysis of Vibromotors with a Free Rotor. Part 2. Dynamic Analysis of Vibroengines with a Free Rotor

V. Ragulskiėnė and L.A. Štacas

Kaunas Politechnical Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 4 (38), pp 171-178 (1981) 2 figs, 1 ref

(In Russian)

Key Words: Motors, Stick-slip response

A dynamic vibromotor model with a free rotor is investigated and the equations for geometrically equivalent moving parts of the vibromotor are derived. The model can predict the separation of the vibrating element from the rotor and the stick-slip motion.

83-2134

Optimum Design of Vibropumps by the LP-Search Method

L.P. Bastytė and A.K. Bubulis

Kaunas Politechnical Institute, Kaunas, Lithuanian SSR, Vibrotechnika, 4 (38), pp 179-185 (1981) 6 figs, 3 refs

(In Russian)

Key Words: Pumps, Vibratory techniques

A unique vibropump design is presented which is based on a simultaneous external high frequency excitation on the walls of the chamber and on the fluid. This coordination of phase effects on the chamber causes the fluid to run on one side of the wall of the chamber. Such pumps are small and are easily controlled. The article presents an optimum design technique of such a pump by means of LP search technique using Sobol points.

AUTHOR INDEX

CALENDAR

NOVEMBER 1983

7-10 Truck and Bus Meeting and Exposition [SAE] Cleveland, OH *(SAE Hqs.)*

7-11 Acoustical Society of America, Fall Meeting [ASA] San Diego, CA *(ASA Hqs.)*

13-18 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] Boston, MA *(ASME Hqs.)*

15-17 12th Turbomachinery Symposium [Turbomachinery Labs.] Houston, TX *(Dr. Peter E. Jenkins, Turbomachinery Laboratories, Dept. of Mechanical Engineering, Texas A&M University, College Station, TX 77843)*

FEBRUARY 1984

22-24 IAVD Congress on Vehicle Component Design [IAVD] Geneva, Switzerland *(Dr. M.A. Dorgham, International Association for Vehicle Design, The Open University, Walton Hall, Milton Keynes MK7 6AA - (0908) 653945.*

27-Mar 2 International Congress and Exposition [SAE] Detroit, MI *(SAE Hqs.)*

MARCH 1984

13-15 12th Symposium on Explosives and Pyrotechnics [Applied Physics Lab. of Franklin Research Center] San Diego, CA *(E&P Affairs, Franklin Research Center, Philadelphia, PA 19103 - (215) 448-1236)*

20-23 Balancing of Rotating Machinery Symposium [Vibration Institute] Philadelphia, Pennsylvania *(Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)*

APRIL 1984

9-12 Design Engineering Conference and Show [ASME] Chicago, IL *(ASME Hqs.)*

9-13 2nd International Conference on Recent Advances in Structural Dynamics [Institute of Sound and Vibration Research] Southampton, England *(Dr. Maurice Petyt, Institute of Sound and Vibration Research, The University of Southampton, S09 5NH, England - (0703) 559122, Ext. 2297)*

30-May 3 Institute of Environmental Sciences' 30th Annual Technical Meeting [IES] Orlando, Florida *(IES, 940 E. Northwest Hwy., Mt. Prospect, IL 60056 - (312) 255-1561)*

MAY 1984

1-3 Mechanical Failures Prevention Group 39th Symposium [National Bureau of Standards, Washington, D.C.] Gaithersburg, MD *(Dr. J.G. Early, Metallurgy Division, Room A153, Bldg. 223, National Bureau of Standards, Washington, D.C. 20234)*

7-11 Acoustical Society of America, Spring Meeting [ASA] Norfolk, VA *(ASA Hqs.)*

10-11 12th Southeastern Conference on Theoretical and Applied Mechanics [Auburn University] Callaway Gardens, Pine Mountain, GA *(J. Fred O'Brien, Director, Engineering Extension Service, Auburn University, AL 36849 - (205) 826-4370)*

JULY 1984

21-28 8th World Conference on Earthquake Engineering [Earthquake Engineering Research Institute] San Francisco, CA *(EERI-8WCEE, 2620 Telegraph Avenue, Berkeley, CA 94704)*

AUGUST 1984

6-9 West Coast International Meeting [SAE] San Diego, CA *(SAE Hqs.)*

SEPTEMBER 1984

9-11 Petroleum Workshop and Conference [ASME] San Antonio, TX *(ASME Hqs.)*

30-Oct 4 Power Generation Conference [ASME] Toronto, Ontario, Canada *(ASME Hqs.)*

OCTOBER 1984

8-12 Acoustical Society of America, Fall Meeting [ASA] Minneapolis, MN *(ASA Hqs.)*

9-11 13th Space Simulation Conference [IES, AIAA, ASTM, and NASA] Orlando, FL *(Institute of Environmental Sciences, 940 E. Northwest Hwy., Mt. Prospect, IL 60056 - (312) 255-1561)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics
1290 Sixth Ave.
New York, NY 10019

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

ICF: International Congress on Fracture
Tohoku University
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IMechE: Institution of Mechanical Engineers
1 Birdcage Walk, Westminster,
London SW1, UK

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
Owles Hall, Buntingford, Hertz.
SG9 9PL, England

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 5804
Washington, D.C. 20375

PUBLICATION POLICY

Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

> **Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].**
>
> **Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .**

The format and style for the list of References at the end of the article are as follows:

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- **titles of articles within quotations, titles of books underlined**
- **abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)**
- **volume, number or issue, and pages for journals; publisher for books**
- **year of publication in parentheses**

A sample reference list is given below.

1. **Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).**

2. **Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addision-Wesley (1955).**

3. **Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Devel. (1962).**

4. **Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., 27 (3), pp 220-231 (1948).**

5. **Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).**

6. **Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).**

7. **Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).**

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